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# Perception, cognition and morphological objectivity

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The study of "form-bearing elements" presupposes the possibility of developing a specifically morphological analysis of sound forms. For that, a physico-mathematical theory of morphogenesis is required. Its role is to suggest morphodynamic models of natural morphologies. In order to comprehend sound forms (and, more generally, perceptual forms) it is not enough to consider them as the "projection" of the results of cognitive processing of physical information onto the external world. For – as opposed to the "methodological solipsism" dominating the classic cognitive sciences, and in agreement with more "ecological" points of view such as David Marr's – recent morphodynamic theories (catastrophe theory, dissipative structures, synergetics, etc.) show that the morphological structuring of the external world is largely the result of physical processes of (auto)organization. These fundamental scientific findings should be incorporated into cognitive analyses.

KEY WORDS: Morphodynamic models, phenomenology of perception, phenophysics, principle of double organization, conceptual structure, projected world, catastrophe theory.

## Foreword

This short article covers only one very specific theoretical point, and is a complement to Francois Bayle's chapter (this volume). It is the work of a mathematician (not a musician) who has applied morphodynamic mathematical models to certain basic cognitive problems such as categorical perception in phonetics (and, more generally, problems concerning prototypicality and categorization), relationships between language and perception, as well as, for example, David Marr's 2½ D sketch of visual perception.

In the following pages, *morphological* refers to everything concerning the (spatio-temporal) qualitative organization and structuring of natural and perceptible forms. *Morphodynamic* refers to models of morphologies and morphogenetic processes based on mathematical theories of singularities and their universal unfoldings as well as of the bifurcations of non-linear dynamic systems.

## Introduction

One of the most striking things about acousmatic music such as that of François Bayle – apart from its specifically aesthetic and artistic qualities – is its wealth of morphological components. The morphological, indeed morphodynamic, lexicon used by the composer in the *phenomenological description* of sound images,

sound structures and sound organizations is very diverse; it includes forms, figurative salience, clear and fuzzy contours, attacks and fronts, not to mention deformation, stretching, mixing, stability and instability, rupture, discontinuity, harmonic clouds, crumbling and deviation of figures and so on. Should this vocabulary be considered as a vague, poetic approximation or, to the contrary, as the demonstration of an authentic morphological component on which higher semiotic levels of musical composition can be built? This second option is adopted here. The hypothesis is that a specifically morphological component of perceptual sound organization really exists, a component on which most *form-bearing elements* can be founded (cf. McAdams, this volume).

What then, is the *cognitive* status of such structures? The problem is a general one extending beyond music cognition. *It is central to the entire field of the phenomenology of perception.* In phonetics, for instance, the phenomena of categorical perception (which discretizes the audio-acoustic continuum and thereby effects the passage from the audio-acoustic level to the phonological level) are eminently morphological phenomena. They basically arise from the fact that phonetic perception of spectral morphologies is *qualitative.* Within the space of acoustic cues which function as control parameters for phonetic percepts, there are areas of *stability* bounded by areas of *instability.* As Kenneth Stevens pointed out in his "quantum" theory of speech, it is this mixing of stability/instability of spectral morphologies relative to control variations that produces the fundamental perceptual effects of *invariance* and *discretization* without which the audio-acoustic *continuum* could not function as substrate for the phonological *code* (cf. Petitot, 1983a, 1985b; Schwartz, 1987). Here it can be clearly seen how the morphological level serves as the basis for the higher – symbolic – cognitive levels of perceptual "languages", conceptual "grammars" and formal "syntaxes" currently undergoing intensive scrutiny by the cognitive sciences. The problem is that, for *intrinsic* reasons, this morphological level is one of the most difficult to theorize. It supports form-bearing elements, but is scientifically manageable only if a *physico-mathematical theory of form and morphogenesis* is made available. Yet following some not very convincing efforts by Gestalt theory, nothing was developed along these lines for a long time. It wasn't until the amazing developments of the early 1970s, such as the theories of morphodynamic catastrophe models, of dissipative structures, and of synergetics, that the situation was completely reversed. There *now* exists a physico-mathematical theory of morphology as such, *a theory to be integrated into the cognitive sciences.* The brief comments which follow will be devoted to this topic, stemming as it does from the epistemology of cognition.

## Conceptual structure and projected world

In order to understand what it means to introduce a morphodynamic component into the cognitivist paradigm, it is appropriate to begin with a particularly relevant conception of cognitivism, the one developed by Ray Jackendoff. In *Semantics and Cognition,* Jackendoff introduced the hypothesis of Conceptual Structure (CS), in order to understand the semantic structure which enables us to speak of what we see: "There is a *single* level of mental representation, *conceptual structure,* at which linguistic, sensory, and motor information are compatible" (Jackendoff, 1983, p. 17). This hypothesis fits into the framework of computational mentalism (classic

symbolic paradigm). Its role is to allow for a better understanding of the structural constraints imposed on a theory of cognition, and of the relationship between universal grammar, cognitive capabilities in general, and the structure of thought. It posits the idea that language "reflects" thought and the world, and that, therefore, there exist *semantic* constraints which determine syntax (these constraints being themselves constrained by perceptual structures).

The CS transforms the real world (RW) of physical objectivity into a *projected world* (PW), namely the *sensory* world as *qualitatively* structured and *phenomenologically* organized, the world of actual experience, the world of phenomenal events. Let us take the classic example, given by Jackendoff, of *color*. In the RW there are electromagnetic waves. The sensory quality of /color/, however, belongs to the PW. It is derived from the processing of physical information by a conceptual constituent, [COLOR], belonging to the CS. [COLOR] is the structure of /color/ as formally expressed in the internal structure of the related mental computation, the relationship between [COLOR] and /color/ raising the classic "mind-body problem" (Jackendoff, 1983, pp. 31-34) (see Figure 1).

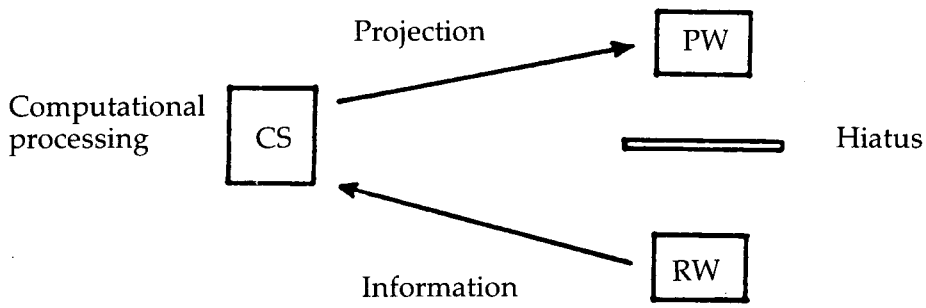


**Figure 1**

The projected world thus described is not, by definition, the real world. But it is not merely the perceived world, either. It is the world "for us" in the *phenomenological* meaning of the term. This phenomenological world is not subjective-relative. It is not an imaginary world of appearances. It is obviously a *cognitive construction* but one which obeys genetic constraints and is therefore universal to the human species.

Jackendoff thus takes up all the central themes of the phenomenological tradition following on the guiding concept that phenomenological consciousness is the correlate of the PW. This means that consciousness is not the same as mental computation. Mental representation is derived from processing, from calculations done by the constituent elements of the CS. But the major part of the internal structure of these constituents (such as [COLOR]) *is not projectable* (which moreover places intrinsic limits on introspection). Internal structure *is not manifest* in phenomenological experience. Which is to say that "projectability" is a basic *property* of the process of constituting the PW. This point of view is further developed in Jackendoff's latest book, *Consciousness and the Computational Mind*. The reconquest of a phenomenological point of view allows for the reintroduction of a *realist* conception of language and perception. Language and perception truly

possess an *ontological* content, but it is a question of the ontology of the PW and not of the physical RW. Starting from these premises, Jackendoff undertakes a cognitive analysis of the CS in its projective relationship to the PW. This leads him to identify *ontological categories* of the PW.

It should be stressed that the CS standpoint represents a phenomenologico-computational mentalist standpoint in contrast to Russell's logic and Wittgenstein's pragmatism. Jackendoff's semantic approach reactivates numerous *Gestalt* and phenomenological problems and therefore inevitably leads to a critique of the various schools of formal semantics. It holds that the level of the CS constitutes the *same* level as that of semantic structure.

## The problem of pheno-physics

Jackendoff's analyses and conclusions are fully endorsed here, with the exception of one major reservation. The phenomenological conception stemming from the CS hypothesis is, as just pointed out, purely *projective*. The PW appears there as a purely cognitive construction and is separated from the physical RW by an unbridgeable ontological hiatus (cf. Figure 1). The hypothesis that there may exist a *natural – non-cognitive – process of phenomenalization of the objective RW* is never raised. Nor is the possibility ever considered that the *qualitative structuring* of the world of things, forms, states of affairs, places, paths, states, events, processes, etc. may *partly emerge* from a spontaneous *morphological* organization of material substrates. In other words, Jackendoff's analysis is limited to a classic objectivist physicalist conception of physics and it is the *subject* (consciousness, the mind) who is responsible for the phenomenalization of the RW into PW.

A prejudice concerning the meaning of physics always legitimates this type of perspective, the prejudice that "it is well known" that physics "cannot explain" the qualitative organization of the world. Now – and this is the point – such "evidence" inherited from the history of modern physics *can no longer be accepted as such*. The past twenty years has seen considerable progress in physics and mathematics in terms of understanding (auto)organizational phenomena of material substrates. This entails:

(i) in mathematics: the theory of singularities and their universal unfoldings; theories of structural stability; the qualitative theory of non-linear dynamic systems and of their bifurcations; theories of turbulence and of the paths leading to chaos, etc.

(ii) in physics and non-linear thermodynamics: theories of critical phenomena in general; the theory of phase transitions and, more broadly, the study of phenomena of spontaneous breakings of symmetry within organized media; the analysis of catastrophes of diffraction and of dislocations of wavefronts in wave optics (caustics, asymptotic solutions to wave equations, approximation of geometric optics, oscillating integrals and methods of stationary phase, etc); numerous applications of the many theories mentioned above in various fields, such as shock waves, dissipating structures in kinetic chemistry and in non-equilibrium thermodynamics, defects in ordered media and in particular in mesomorphic phases (liquid crystals), etc.

All this converging research, the work of some of the most eminent contemporary scientists and engaging an enormous physico-mathematical problematic, has profoundly – radically, it could even be said – modified the image of physics. Three guiding concepts have been developed:

(i) In general, natural systems – such as thermodynamic systems – possess (at least) two levels of objective reality: a "micro" level, "intricate" and complex, corresponding to the system's fundamental physics, and a "macro" level, coarser and usually finitely describable, more of a morphological than of a physical nature. The "macro" level *emerges* from the underlying "micro" level and this process of transition can be mathematically checked, using models. It basically results from the coordinated and cooperative collective behavior of local "micro" entities (cf. statistical mechanics in thermodynamics, aggregation theory in economics, or connectionism in cognitive science).

(ii) The "macro" level is essentially organized around singularities (caustics, phase transitions, shock waves, defects, breaks in symmetry, etc.) of underlying physical processes. These singularities carry information and are phenomenologically dominant ("salient" to use Thom's term). The qualitative structuring – the morphological organization – of phenomena is thus effected through them. Spectacular examples of this include the explanation of caustics in terms of oscillating integrals and the explanation of phase transitions in terms of renormalization groups (cf. Petitot, 1986b).

(iii) There are abstract (formal, "platonist"), mathematically formulatable constraints imposed on critical phenomena in general. Analysis reveals strong properties of *universality* on critical behavior, that is to say a notable *independence* of organization at the morphological "macro" level (according to morpho-structural rules).

One can therefore properly speak of an emergent and autonomous *morphological level* as well as of *catastrophic infrastructures* of phenomena. Following a suggestion made by Per Aage Brandt, the neologism *pheno-physics* will be used to refer to this morphological level: basic physics can be understood as a sort of "genophysics" which is "pheno-physically" *expressed* through a morphological level possessing a relative autonomy and its own structural laws of organization. Pheno-physics deals with a morphodynamic approach to what is now currently called "qualitative physics."

The physicalist and objectivist prejudice mentioned above can then easily be formulated as follows: *no pheno-physical level exists*. This implies the corresponding projectivist cognitive thesis. But since the physicalist argument is no longer tenable, the projectivist thesis should be revised: *the phenomenological world – the natural sensory world (NW) – is both projected and pheno-physical*. There is therefore no ontological hiatus between PW and RW. The diagram presented above should be revised as in Figure 2.

Based on René Thom's work, a certain number of my articles have already offered detailed analyses of the status of pheno-physics (Petitot 1982a,b, 1983a,b, 1986a,b, in press-a), involving epistemological investigations of its physico-mathematical contents. Through these works, I dealt with – in my own way – most of the topics raised by Jackendoff long before I became aware of *Semantics and Cognition*. For example:

(i) The Gestaltist reconstruction of a form from its apparent contours. Here it is a

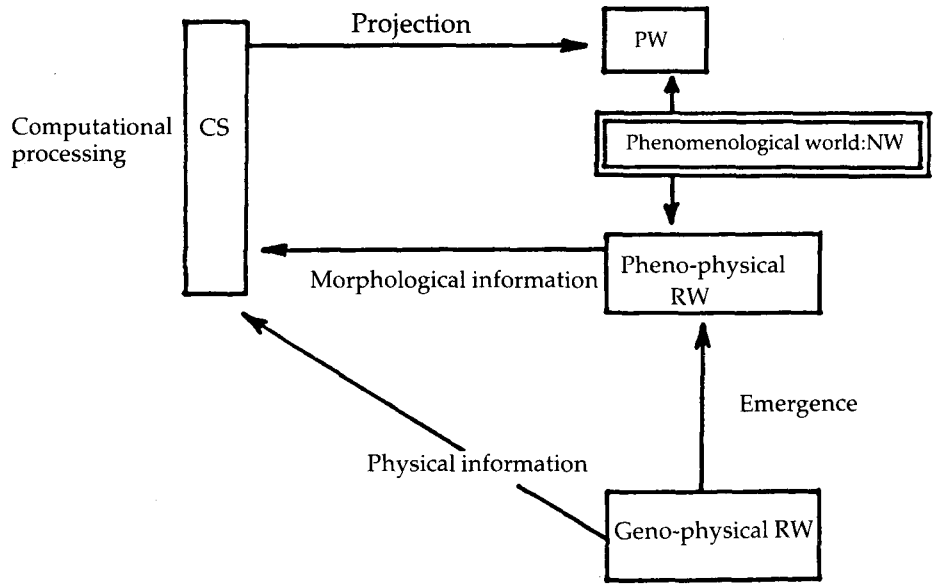


**Figure 2**

question of confrontation between Husserl's phenomenology and contemporary cognitivism, especially as developed by David Marr in *Vision*, where the intermediate level of the 2½-D sketch corresponds quite closely to Husserl's concept of perceptual adumbrations.

(ii) Problems of categorization and typicality. This involves interpreting the type-token dialectic in the context of the theory of structural stability, as well as the way a space can be categorized so as to become a paradigm (in the structuralist sense). As already pointed out, this is especially important for phonological paradigms and categorical perception (Petitot 1983a, 1985a, 1986c).

(iii) The localist hypothesis in structural syntax and perception–language relations (Petitot, 1988).

(iv) An explanation of the intentional orientation of consciousness.

This convergence reinforces the idea that an authentic phenomenology of the organization of the worldly substance should be not only projective, but also morphological (realist), thereby linking cognitivism to a philosophy of nature in the context of a search for a "physics of meaning" or, as Thom likes to say, a "semio-physics".

## The principle of double organization

In order to integrate a specifically morphological component into a cognitivist phenomenology like Jackendoff's, the standard symbolic and functionalist (computational-representational) paradigm must be significantly transformed. For this

paradigm, symbolic mental representations are expressions of an internal formal language referring to the outside world by processing external physical information (understood in the geno-physicalist sense of the term). It is posited that "contact with the world enables the cognitive system to supply meaning to its internal symbols" (Andler, 1987, p. 7). In other words, it is posited that "the structural properties of the world are expressible, using a fairly rich formal language, in the form of facts and rules" (Andler, 1987, p. 8).

This perspective immediately gives rise to a weighty problem which Zenon Pylyshyn, in *Computation and Cognition*, calls the problem of the "bridge from Physical to Symbolic". From an objectivist physicalist standpoint, external physical information being *a priori* non-symbolic – and therefore without prior computational signification – it should be recognized that the interface between the cognitive system and external reality is reduced to the operation of peripheral modules – transducers – which convert this information into computationally significant information. This is obviously necessary since, in order for symbolic representations to represent (i.e., to possess semantics), they must be truly correlated with external physical events. Pylyshyn himself opts for a strict dualism as opposed to the monist naturalism sketched out here. For Pylyshyn, there is an *irresolvable* break between the cognitive (symbolic) and the physical. There is no physicalist description of inputs which are usable by a cognitive system (Pylyshyn, 1984, p. 166). The functional cognitive lexicon is without physical content. And given this "general failure", (p. 167), the transducers converting physical inputs into system-usable inputs must therefore deplete the "objective" ontological content of cognition, the remaining ontological content being projectively defined according to PW ontology.

Two enigmas remain, within this dualist paradigm.

(i) The object enigma – already mentioned – of *forms*. That is to say the enigma of the specifically morphological dimension of the natural sensory world.

(ii) The subject enigma of *meaning*. "How does meaning become affixed to the symbol?" (Andler, 1987, p. 18). As many authors have pointed out (Searle, Putnam, Dreyfus, etc.), the symbolic paradigm does not provide a good theory of the *interpretation* of mental representations nor of the *intentional* orientation of subjects toward objects (cf. Proust, 1987).

I think that a *double* theory of emergence is needed in order to shed light on these two enigmas. The object enigma requires the development of a phenophysics based on morphodynamic models of critical and (auto)organizational phenomena. Whereas the subject enigma urges elaboration of Thom's and Zeeman's seminal idea that a "macro" content can be assimilated to the topology of an attractor of an underlying "micro" dynamic, and that logico-combinatorial structures of competence must therefore be interpreted as stable and emergent regularities in the context of the theory of bifurcations of non-linear dynamic systems (yielding a principled analogy with thermodynamic models of phase transitions). This idea has been recently rediscovered and refined by *neo-connectionist* models of performance in the context of the so-called sub-symbolic paradigm. From a connectionist standpoint, entities possessing a semantic content are, at the micro level, complex and global patterns of activation of elementary local units which are interconnected and function in parallel. Semantics is therefore an emergent holistic property. Discrete and serial symbolic structures

on the "macro" computational level (symbols, rules, inferences, etc.) are then interpreted as qualitative, stable, invariant structures emerging from the sub-symbolic level through a *cooperative* process of aggregation. Which leads back to the principled analogy with phase transitions. If, as Paul Smolensky suggests, a *harmony function* is introduced here (as the cognitive analog of thermodynamic *energy*, just as information is the analog of entropy) whose optimization defines *coherent and consistent* global patterns (Smolensky, 1986), then one arrives at the conclusion that sub-symbolic cognitive systems behave so as to optimize this potential function. Which naturally brings us back to models of the "catastrophe theory" type.

The natural world of phenomenological manifestation thus becomes the product of *three* interdependent processes:

(i) The emergence of a symbolic conceptual structure from an underlying sub-symbolic dynamic level;

(ii) The projection of this CS ("computational mind") onto the Consciousness – Projected World correlation;

(iii) The emergence of a pheno-physical morphological level from the geno-physical level.

This leads to the formulation of the following principle, challenging Pylyshyn and Fodor's projective and dualist notions: *Several* levels of reality exist whose ontological content is *objective;* the basic physical level (in the physicalist sense), of course: light waves, sound waves, etc.; but also the intermediate morphological level as well as the higher level of movements of objects in three-dimensional space. *Autonomous* (non-computational) mathematical and physico-mathematical theories of these objective levels are already available. Then from the subjective standpoint, several levels of *information explicitness* also exist. *And some of these levels possess objective levels of reality as objective correlates.* Consider the *visual form of objects,* for example, where the three basic levels of David Marr's perceptual theory all possess mathematically describable objective correlates:

(i) optics (geometric and wave) for the peripheral 2D primal sketch: propagation of wavefront singularities representing the apparent contour of objects, and their detection by zero-crossing criteria;

(ii) theory of singularities (Thom and Arnold's catastrophe theory) for the intermediate 2½-D sketch: apparent contours and reconstruction of a form based on the family of its apparent contours, etc.;

(iii) classic geometry and mechanics (Lie groups, movement of solids, etc.) for the central 3D level.

These objective theories are not computational. But they define *types* of information. The principle of double organization, as opposed to Fodor's (1980) "methodological solipsism", *finalizes* computational theories through objective theories: *when a level of explicitness (of representation) of information possesses an objective correlate it is the objective theory of this correlated reality which should determine the computational theory of information explicitness.* In other words, it is the *objective* determination of the *type* of information which must determine the theory of information processing.

This principle of finalization, when applied to the foregoing, is formulated in

the following way. Information serving as input to the cognitive system is not only physical but also morphological. It is *pre-organized* in a way which is already system-significant on an *objective* basis. But this significance probably does not directly concern the symbolic level. A natural hypothesis is that it concerns instead the *sub-symbolic* level. Since the sub-symbolic and pheno-physical levels are governed *by morphodynamic formalizations of the same type*, it is easier to understand how one can *simulate* the other. Once represented at the sub-symbolic level, morphological information moves back toward the conceptual structure and, through projection onto the phenomenological level, transforms the natural world into a projected world. This is known as the *principle of double emergence and double organization* of the natural world (see Figure 3).

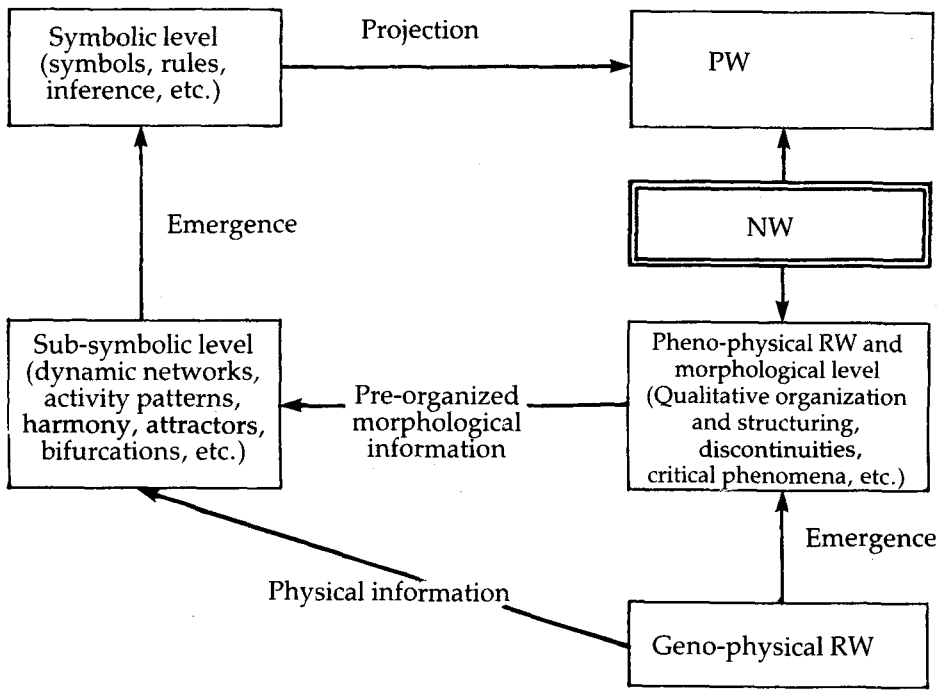


**Figure 3**

## Conclusion

Theories of signal analysis, digital signal processing technologies, and the focus on symbolic representation – all of which are typical of computational mentalism – could be notably enhanced by taking into account the morphological information which is encoded through singularities. For the basic role of detectors of significant features is to reconstruct the geometry of these singularities. This is beginning to be appreciated, as indicated here, by theorists of visual and phonetic perception. Will it perhaps soon be appreciated by those concerned with musical perception?

*Translated from the French by Deke Dusinberre*

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