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Language as a system of replicable constraints

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For a psychologist interested in language processing, working in the beginning of the 90s was not at all easy. On one hand, we had at our disposal methods of traditional psycholinguistics, with its information-processing models consisting of symbols, rules, parsers, and mental lexicons. Most of the body of knowledge about language processing gathered since mid-20th century was due to research motivated by this approach and its methodology. On the other hand, we were very much aware that the use of language involves time-dependent dynamical processes taking place both within and between individuals and involving physical stimuli, the nature of which, on the first sight, was not obviously symbolic.

The recent (at that time) successes of neural network models of processes, such as word recognition (McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989; Kawamoto, 1993), emergence of structured semantic representations (Elman, 1990) or models of language dysfunctions, such as aphasia (Hinton & Shallice, 1991), strengthened the claims that casting explanations in dynamical terms has clear advantages. A hopeful question arose: can we build models of language solely in terms of dynamics, treating expressions of natural language just like any other physical stimuli, instead of endowing them with symbolic properties?

Following this line of thought, it was natural to ask: can *any* cognitive phenomenon be described without referring to symbols but at the same time without endorsing the behaviorist exorcism of mediating mental states? After all, what is a symbol? How is it different from a physical stimulus? Has anybody ever seen one in the brain? Would anything important be lost if explanations of cognitive phenomena were built solely in terms of dynamical, self-organizing brain states, that adapt responses to the demands of the environment? When and why would the necessity of a symbol in an explanation of cognitive functioning arise? In what kind of cognitive system? Perhaps it would be easier to ask this question not about human cognition, which intuitively seems sophisticated and saturated with symbols, but about any living organism that uses memory to adapt to its environment? Do we really need to talk about symbols even at this level? And if yes, what kind of symbols are they?

Led by a naïve faith of a graduate student that some answers are surely just around the corner and can be discovered by talking to experts and reading several books, I started systematic discussions of these issues with Scott Kelso, from the Center for Complex Systems and Brain Sciences (CCS) at Florida Atlantic University, while being inspired and supported in research ideas by other faculty at the Center, most notably Betty Tuller. These scholars made the Center for Complex Systems a home of intense intellectual life and research adventure. At that time CCS was one of the very few places in the world where the complex systems' approach was tested in the domain of psychology, bringing new hope for an alternative framework for studying cognition. At the same time, I was being sobered in my dynamicist zeal by the parallel debates of the same issues with Lewis Shapiro, a Chomskyan psycholinguist, who supervised my dissertation on the processing of ambiguous expressions. Especially during numerous exchanges with Scott Kelso I realized that my questions about psycholinguistcs are actually versions of much more basic ones, concerning the bare fundaments of how living things retain and use previous experiences.

Most impressive, from among the literature read and discussed at the time, was the work of physicists that aimed at accounting for informational properties of living matter, such as Robert Rosen, John von Neumann, Alan Turing, and Michael Polanyi. They showed that the quest for the clarification of the nature of intelligence, i.e., the nature of information that enables adaptive functioning of organisms in their environments, had to start at the very beginning of life or at least at the level of very basic principles that make evolution and adaptation possible.

That symbols were thought necessary for these properties was, obviously, not a revelation in the 90s: after all, the information-processing approach, which emerged 40 years earlier was based on this claim. But it wasn't until Kelso suggested that I read the papers of Howard H. Pattee that it became clear that there was a different interpretation of the necessity of symbols in cognition than the one later embraced by the cognitive sciences. In other words, the symbols that were recognized as necessary in the explanation of adaptive complexity of organisms (e.g., von Neumann's necessity of a self-description (1966)), and in the explanation of human problem solving powers, were mistakenly but all too often identified with the things that computers crunch (see, e.g., Newell and Simon's Physical Symbol System (1976)).

Even though alternative, more cautious, ways of conceptualizing information in living systems were already present (e.g., in later papers of Turing (1952), Polanyi (1968), or Rosens, (1969, 1991), Pattee's work was the most comprehensive, in its building from the biological necessity of certain kinds of symbols for control processes to the consequences that doing so would have for memory-based systems in general. Besides, Pattee was able to take a stance informed by important theoretical divides present at the time, and that are still present now. For example, he was active in the discussions between proponents of the information processing approach and of more dynamically oriented 'ecological psychology' approach to cognition (Pattee, 1982a,b), arguing for the insufficiency of both symbolic and dynamical explanations alone. Perhaps it was this breadth of scope paralleled by the concreteness and precision of the claims that made his work accessible and potentially relevant to the problems we faced in psycholinguistics.

The perspective presented by Pattee changed, and keeps changing, my thinking about language and cognition in general. And I think that Pattee was right in suggesting that it has the potential to forge a third way, alternative to the two dominant approaches in cognitive sciences: the information processing approach and the dynamic approach. This third way is based not on showing that one of the approaches is reducible to the other but on retaining both as complementary models. If this way of thinking about symbols and matter is to be considered, re-constructed, and developed further, it is essential to present biologists, physicists, cognitive scientists and semioticians with the original papers that Howard Pattee wrote from the 60s to the present. Doing so can provide a solid base from which the hidden assumptions about the role of symbols in living organisms can be made explicit and perhaps questioned within the particular field of study that each of these very different kinds of scientists represent. In the case of the cognitive sciences, this means putting in doubt too uncritical interpretations of the human brain as some kind of computing device, as well as equally too enthusiastic attempts to eschew symbols entirely from our explanations.

In what follows, I will trace the consequences of adopting Pattee's original ideas on the nature of symbolic constraints as informational structures in living organisms for the theory of natural language, and will draw some of its more general consequences for the theories of cognitive processes. Pattee's framework brought several essential shifts in the understanding of very basic terms — such as "symbol", "model", "language", "code", and "communication" — which since the middle of the last century have become crucial in the vocabularies of cognitive scientists and linguists. Accordingly, the first part of this commentary will be devoted to a summary of these shifts from the perspective of a psycholinguist, which means I focus on certain aspects, and elaborate some of them beyond Pattee's work — for example, the importance of the history of physical events for the constitution and workings of symbolic constraints, the coordinative role of the constraints, or the problems encountered while considering referential properties of symbols within a coordinative framework.

Secondly, while Pattee emphasizes that similar basic principles underlie heritable memory structures of a developing cell and language, he also makes it clear that the two informational systems are vastly different. The second part of this paper aims at finding the core similarities and delimiting the range of issues in the theory of natural language that are particularly affected by the abovementioned shifts.

The third section describes the consequences of the application of Pattee's framework to the natural language phenomena. Applying to them concepts enumerated in the first part of the paper means rejecting or loosening some of the assumptions that constitute the basis for many existing theories of language and linguistic functioning. I will show the benefits gained from adopting such a perspective, i.e., the fresh look it affords on the reasons behind ever-recurring problems in linguistic theory, and the suggestions of new directions for theory construction and research that are implied by it. I will also draw attention to the specificity of natural language among other natural informational systems, which will stand out clearly once the common background of basic principles is accepted.

Finally, I will show that the shifts that have to be made are not total discontinuities, and that the traditional ways of looking at natural language can be and should be subsumed within this more encompassing framework — one that actually calls for the parallel and harmonious co-existence of symbolic and dynamic modes of description. In this section I will also venture into the general theory of cognition to expand on the claim expressed above, on the reconciliatory potential of Pattee's work. The most crucial principle of his approach, the necessity of the co-existence of complementary models to describe informationally based processes in nature, indicates a third way, mediating between the two most dominant approaches in cognitive science: the information processing approach and dynamical approach of ecological psychology. **I will argue that this is a way of looking at cognitive phenomena that allows one to be a non-reductionist while remaining a materialist.**

I. Information in biology: the complementarity of dynamics and symbols

The main arguments of Howard Pattee's approach can be found in his original papers. His commentary upon that work in this volume provides his contemporary summary and, at times, qualifications. Thus it might seem that my recapitulation of his main arguments in this section would be redundant. I do not believe this to be the case, however, in that I think it is important to explicate his basic arguments in a slightly different language and from a slightly different angle. This, I think, will foreground these explicit views as well as their unstated implications that have the strongest impact on our thinking about natural language, a topic that Pattee's work is not itself primarily concerned with.

The necessity of using complementary models that is advanced in Pattee's framework leads to seeing in symbols not only their formal properties that have always been appreciated but, above all, their physical nature. In a biological organism, what we call a symbol is always a physical structure that obeys the laws of physics and interacts with the dynamics of a particular system according to these laws. Analyzing this physical nature, the exact physical requirements for something to become a symbol, and the processes that symbolic structures are engaged in, makes one realize that the physical realization is far from being inconsequential for the "formal" properties. This brings about the shift from understanding symbols as "formal entities substituting for something else" to seeing in them "replicable constraints in a particular dynamical system".

Below I will expand on Pattee's postulate of complementarity and the claims about the properties of symbols that follow from this change of view regarding the relation between symbols and dynamics. Among the most important ones are that: a) symbolic structures are **physical structures**, b) they are **replicable (transmittable)**; c) they act as **selected constraints**: i.e., have a history within a system. Further, d) their constraining role consists in **harnessing dynamics** in a particular way, which e) is best seen as a functional **coordination** of the parts of the system, be it in morphogenesis or shaping functional behaviour. Importantly, f) such **constraining is continuous**: symbolic constraints may leave a variable role to dynamics: from completely harnessing it to allowing large contextual flexibility.

1. Control in living systems requires complementary models

Pattee's work was initially concerned with information in living systems at a very basic level — i.e., analyzing how systems that obey physical laws can undergo evolution. This investigation went in two directions: one was to spell out the physical conditions for the emergence of memory structures capable of ratcheting the adaptive complexity of an organism in the face of environmental challenges (e.g., Pattee, 1968). The second was an attempt to answer an old question about the sufficiency of the physical laws to account for such memory structures (Pattee, 1969). The outcome of this work was Pattee's conclusion that two complementary models are necessary for the explanation of informational processes in living organisms, along with a list of necessary physical conditions needed for memory structures to emerge.

Pattee treats complementarity as a very basic and universal epistemic necessity, always present when a functional reduction of degrees of freedom is made and recorded in a system. He addresses specific examples, including the contexts in which this notion usually appears in the scientific literature, such as the distinction between laws and initial conditions, and the complementarity principle in quantum mechanics. Other authors point to self-organization and emergent phenomena as requiring more than one mode (or rather level) of description (e.g., Kugler & Turvey, 1988). However, the complementarity that is relevant for the study of natural languages can be recognized without descending to the level of quantum description — and for reasons different than the appearance of a novel level in a self-organizing system.

The impossibility of using just one model rests in the fact that the constraining role of a memory structure within an organism depends on something more than just the laws of physics alone: it depends also on its history within a particular system, which includes the irreversible and probabilistic process of natural selection. The way in which a memory structure constrains dynamics is selected on the basis of the adaptive properties of the phenotype (i.e., the effects of the constraints' action) and the transmittability of that structure. At any point in time, the dynamics itself, as a reversible process, can be described by the laws of physics. *How* it is and has come to be constrained by the selected structures to bring about adaptive functionality in an environment will, however, escape this description.

Pattee's work elaborates on the views expressed in the work of two prominent figures of the time: Michael Polanyi and John von Neumann. Polanyi, in his "*Life's irreducible structure*" (1968) points out that any system that harnesses natural dynamics to perform *useful* work, be it a machine or a living system, is under "dual control". On one hand, it has to conform to the laws of physics, but at the same time it possesses a structure, a design, which provides the boundary conditions within which these dynamics work.

> *"(...) if the structure of living things is a set of boundary conditions, this structure is extraneous to the laws of physics and chemistry which the organism is harnessing. Thus the morphology of living things transcends the laws of physics and chemistry."*
> Polanyi, 1968, p. 1309

Laws of inanimate matter can thus serve as explanations of systems *within* their existing boundary conditions (including self-organization phenomena). However, the boundary conditions themselves require a complementary description. This claim is perceived by Polanyi as liberating, rather than limiting: "*recognition of the impossibility of understanding living things in terms of physics and chemistry, far from setting limits to our understanding of life, will guide it to the right direction*" (p. 1312).

Polanyi talks about "alternative" description — but does not specify *how* this description differs from ones formed in terms of physical and chemical laws. The proposal of "symbols" as terms of this description appears in Pattee's papers together with appreciation of the work by John von Neumann and other theorists of computation. Von Neumann advocated the logical necessity of the existence of a separate structure in the case of evolvable organisms, i.e., "that information in the form of non-dynamic symbolic constraints ("quiescent" descriptions) must be distinguished from the construction dynamics they control in order to allow open-ended evolution." (von Neumann, after Pattee (2006, p. 225)). It is also important to note, for the later discussion of generalized and natural language, that in his theory of self-replicated automata, von Neumann has demonstrated that there is a threshold of complexity below which sustaining such transmittable structures is not possible (von Neumann, 1966).

2. Rethinking the nature of symbols

The existence of such potentially functional (or meaningful) structures in an organism is thus seen as a necessary condition for the adaptive increase in complexity. On the other hand, it is admitted that accounting for their functionality requires a different description than can be given in terms of laws of physics. **A physical structure becomes a boundary condition because of its history in the system, including natural selection**. These non-dynamic (with respect to the current dynamics of a system) and replicable structures Pattee calls "symbolic" constraints, and their systemic structure – a "language" (e.g., Pattee, 1972). They are discrete, reproducible (transmittable) and they serve as the instructions to re-construct a system (von Neumann, 1966). However, their inseparability from and reliance on dynamics makes them quite different from how formal symbols are usually understood. In what follows, I elaborate on the essential features of such "replicable physical constraints", concentrating on those that contrast with 'symbols' as the term is usually understood — i.e., as elements of purely formal systems.

a. Symbolic structures are physical

The informational structures in biological organisms, even though their role requires an alternative description to the ones posited in terms of the laws of physics, nevertheless are not abstract: they remain physical structures.

"(...) all forms of codes, rules, or descriptions, even the most abstract and symbolic, must have a definite structural basis." Pattee, 1973

Thinking about symbols not as abstract entities but, rather, as physical constraints has many consequences; let me mention two that seem the most profound: i) being physical, they can be in a non-mysterious way causally related to the processes they control; ii) both their workings and their copying have to obey physical laws and have to be stable and reliable under these laws. Both claims put conditions on the apparent "arbitrariness" of symbols as carriers of replicable constraints.

It is very important to note that the necessity of dual description does not imply a Cartesian dualism: all the constraints on dynamics ARE physical structures, obeying the laws of physics. What makes a molecule a message (i.e., endows it with the power of physically harnessing the dynamics) is not its particular physical or chemical properties, but its evolutionary history within a system: i.e., its being selected for bringing about a particular phenotypic effect. What makes an interaction between molecules 'executing a constraint', i.e. something more than physical interaction or collision, is the selection of the effects of such an interaction, based on the previous history of a structure within a system. *This* is what makes the constraints 'meaningful.'

"*We are taught more and more to accept the genetic instructions as nothing but ordinary macromolecules, and to forget the integrated constraints that endow what otherwise would indeed be ordinary molecules with their symbolic properties*." (Pattee, 1972, 249)

b) Symbolic structures are replicable (transmittable)

In order for a physical structure to be selected as a constraint and to further serve as a memory, it has to be stable enough to be copied, and its replication should be relatively energetically cheap. Transmittability means that symbolic structures in living organisms undergo two different, independent processes of 'reading': 1) as controls, i.e., functional constraints on dynamics and 2) as structures to be copied. In the second process, the functional "meaning" of a constraint should not matter, while the physical structure itself undergoes replication.[1] It is important to note that both processes are sources of selection criteria determining the shape of symbolic structures (i.e., those are selected that constrain functionally and that transmit well).

c) Constraints are selected

In order for these structures to be "informative", i.e., being able to send the dynamics on an adaptively functional path, at the moment of their action they must be physically indeterminable. If we take as an example the informative properties of DNA, the crucial thing is that it is highly improbable that its physical structure, e.g., the order of the bases, would appear by natural laws in a single given moment. **Its presence in a system and its shape may be explained only by reference to a process that takes place on a different time scale than that of its current, constraining action.** Specifically, it is the process of the natural selection of successful phenotypic forms, which arose under the control of such informational structures, that explains the functional nature of a current structure. In Polanyi's words, it is

[1] However, the value of a constraint in a system may be linked to the reliability of copying (i.e., copying of particularly important constraints may be additionally warranted by error-correcting mechanisms).

the very improbability of its occurrence that enables such a structure to be an information structure (Polanyi, 1968).

The improbability of a structure in a given moment determines its informational value (according to Shannon's definition of information), but, obviously, does not say anything about the meaning of such a structure. As Polanyi says: *"(...) the improbability count gives the* possible*, rather than the* actual *information (...)*" (p. 1309). The actual meaning of the structure is the construction, under its control, of the morphology of the offspring, functionally adapted to its environment. Thus 'how informative a structure' is (the quantity of information) does not have a straightforward relation to its meaningfulness, i.e. the epigenetic construction of shape or behavior.

Selection is a **historical** process that underlies current function. The particular history of a symbolic structure in a particular system is crucial for determining its meaning. A constraint will behave just as would any other physical structure on which physical laws act here and now. But its being in a particular place at a particular time is historically determined. One of the crucial conditions for selection is variability — thus the capacity of low-cost variation in structures is an important feature of potential informational structures.

d) The constraining role of an informational structure consists in harnessing dynamics

Symbols do not "carry" any meaning by themselves, nor do they, in any easy way, map to or "represent" external world: "*It is useless to search for meaning in symbols without complementary knowledge of the dynamics being constrained by the symbols*" Pattee (1987 p. 337). Symbols harness a system's existing dynamics so as to generate a specific structure or behaviour. The meaning of such a symbolic structure is what it *does* with these dynamics. Thus, in its evolution and selection, such a structure 'relies' on natural dynamics to construct functional structures or behaviours. This is why so little information can control such complex construction processes. Even more importantly, this is why it is misleading to talk about transmittable constraints as "representations" or "models" of the external world.

Symbolic structures are, rather, **memories of the choices** of adaptive coordinations with reality, of constraints on existing dynamics that have led to adaptive results. They are 'memories' of past decisions made at systems' dynamic bifurcations. Understanding symbolic structures as constraints on existing dynamics unburdens them from the role of being the sole meaning-carriers. The important part in realizing meaning falls on dynamics. This, in turn, assures that informational constraints are flexible, and that the outcome of their action is adapted to a concrete system and situation. Forces active in a specific physical system and situation in a given moment are part of the meaning construction process.

Another important implication of this understanding is that since symbols arise from and control dynamics, the causes for symbols' structures should be sought in these dynamics and not (or not only) in a system of rules existing somewhere independently of them. Analyzing such systems in a structuralist manner may uncover interesting regularities, but such description of these systems is just that: a description. Without accounting for the underlying dynamics, it cannot constitute an explanation (Rączaszek-Leonardi, 2009b). Thus, in the study of a system of symbols it becomes of primary importance to uncover the types, time-scales and systems within which the relevant dynamics take place.

e) Constraints reduce (coordinate) degrees of freedom.

Constraining a dynamical system of many parts in a functional way requires the selection of its relevant degrees of freedom so that it can generate an adaptive structure or perform an adequate behavior. This, in behavioral sciences, is termed "coordination" (Turvey, 1990). Seeing the symbolic role as coordinative brings a shift in our understanding of communicative processes in the direction of coordination, rather than transfer of information. In physics, the term ‘coordination’ is typically used to describe temporal coherence. In this context, however, selection processes assure functionality — thus, coordination through symbolic constraints imposes **functional temporal coherence** on a system that has its own natural dynamics.

f) Constraining is gradual
Functional constraints may play a variable role in constructing a structure or organizing behavior, relative to natural dynamics. Constraints may harness the dynamics completely (which probably rarely happens in biological systems) or leave more space for its role, thus making the outcome less predictable and more contextually flexible.

The properties of symbols listed above are necessary for any physical system to retain and to pass on information. I chose to describe those characteristics here, because they are incongruent with the traditional views on symbols, and because they will be particularly important for thinking about natural language. However, before I turn to that discussion, the grounds for making such generalizations have to be specified.

II. Delimiting the scope of generalization

Pattee’s initial work, as mentioned earlier, was geared towards seeking the principles underlying the origins and transmission of informational control in biological systems. This work had consequences for the philosophy of biology, positioning this science in relation to the physical sciences, in its tackling of problems such as physical preconditions of information generation and transmission in living organisms, on the one hand, and the limits of description in terms of physical laws on the other. Pattee himself initially seemed most interested in the consequences of his work for the origin of life problem. Later however, since the 1980s, he developed his ideas on the applicability of the principle of complementary modes to cognitive and cultural systems. It is important to see why this framework can be applied to such different and evolutionarily distant systems of symbols.

1. On symbols tame and wild: Natural language is not a formal system of symbols

Above I listed those characteristics of the symbolic system of constraints in a living organism that require us to rethink our stereotypical notions about symbols. It is clear that the properties of symbols and their meanings derive from the reliance on dynamics that the constraints evolve with. As such, these symbol systems do not seem to be easily translatable into formal symbol systems, that can be transformed by syntactic rules without reference to their meaning. What then could their relation to formal systems be? One might see formal symbol systems as a subtype of this more general class — a subtype, in which the dynamics are artificially reduced to the point of being inconsequential[2]. In other words, formal symbols do not rely on lawful dynamics for their meaning; in fact, they do not *have* a meaning, until one is externally given.

Now, a question arises: How justified was the mid-20 century claim that both cognitive and linguistic processes were describable in terms of (or reducible to) this narrow subclass of symbolic systems? The computer metaphor for human cognition meant just this: judging cognitive processes to be computable on any kind of machine (e.g., Turing’s universal machine) meant casting those processes in terms of computable formal symbols. Yet

[2] By this I mean inconsequential within the system. The dynamics that makes transformations within such a system meaningful is, artificially, pushed out into the larger system — i.e, that of a person using the formal system.

wasn't this an approach dictated by the fact that these were the symbols most familiar to our thinking? Or was the approach dictated by practical reasons — i.e., by the availability of devices that can process such symbols? In Pattee's words:

> *"(...) I have argued that the most fundamental concept of a constraint in physics depends on an alternative description, and that the apparent simplicity of constraints is in fact a property of the language in which it is described"*
> *Laws, Constraints, Symbols and Languages*, p. 248

In other words, no one denies that explanations of cognitive and linguistic phenomena need symbols. These processes are claimed to have symbolic properties that require alternative descriptions to the ones in terms of laws of physics, but describing them as formal symbolic systems obscures their true nature.

Formal systems require abstracting from dynamics, an "overdetermination" of the result, because they arose for very specific human purposes. This kind of formal precision is not required for cognition in the wild. On the contrary, context-insensitivity (stemming from "cutting off" the dynamics) and "exactness" of the processing, determined only by the form, would most probably prove deadly — leading to the inflexibility of a living system, and its helplessness in the face of error. Moreover, from the theoretical angle, not acknowledging dynamics puts the burden of explanation exclusively on formal symbols. Reconstructing the dynamics in explanatory models in terms of formal symbols becomes cumbersome and unnecessary.[3]

Making the conceptual shifts in understanding symbols in our thinking about natural language, brings both theoretical and methodological advantages. Language, unlike other aspects of cognition has an intuitively clear symbolic level, and thus is especially prone to the attempts of "fast formalization." In fact, one of the key factors that brought about the "cognitive revolution" was the conceptualization of language as generated by a formal system, and therefore as a phenomenon completely describable on the symbolic level (Chomsky, 1957).

On the other hand, by the very same virtue of being based on distinguishable symbol-like, sequential entities, language shows affinities with the genetic information structure in living organisms (e.g. Jacob et al., 1968, Bernstein, 1965, as quoted in Jakobson, 1989, p. 442, 444). In fact, the metaphor of "language" in reference to the workings of genes appeared both in biology and in linguistics (Jakobson, 1989, p. 442-446), most intensively after the discovery of the mechanisms behind biological information transmission by DNA. Sometimes, however, it is not clear what *kind* of 'language' is supposed to have this "strict analogy" to the genetic information system: is it the natural human language, the formalized version of that language, or an abstract formal language? If it is natural language, what properties justify this analogy?

For Pattee, as he states in his commentary, the use of the term "language" to address biological information processes was quite natural and consistent with the *Zeitgeist* of the time. As I understand the scope and intension of the term, on the basis of his papers written over several decades, he delimits a certain very basic phenomenon that is assumed to be **the same** both in the system of information transmission in biology, and in natural language. This core "rudiments of a theory of symbol systems" (Pattee, 1980), is the property that enables the

[3] A good example is the attempt to express dynamics present in the external world as a set of discrete stimuli in the early theories of perception (e.g. feature detection theory). Gibson's theory of perception was a reaction to such attempts and a way to let dynamics back in (e.g., Gibson, 1960, 1966).

transmission of useful constraints on dynamics. Thus, the term 'language' pertains to all phenomena that are based on this general relation of physical system of transmittable structures to the dynamics around which it arose:

> "*My approach is to generalize measurement and linguistic functions by examining both the most highly evolved cognitive systems and the simplest living systems that are known to have the potential to evolve, and abstracting their essential and common measurement and linguistic properties. I want to emphasize that when I speak of molecular language strings and molecular measuring devices I am not constructing a metaphor. Quite the contrary, I mean to show that our most highly evolved languages and measuring devices are only very specialized and largely arbitrary realizations of much simpler and more universal functional principles by which we should define languages and measurements.*" Pattee, 1985, p. 268.

By giving this minimal, but specific, intension to the term, Pattee, like the abovementioned biologists and linguists, allows its extension to include phenomena that few contemporary linguists would call a language. The term is thus applied to biological phenomena in a literal, non-metaphoric sense: the claim is *not* that biological information transmission is (in some respects) like the human language — but, rather, that both cultural and biological information transmission require a generalized language, and that that some basic element that exists in each of them is exactly the same.

This insight has at least two important terminological consequences: 1) that in order to talk about specific instances of such constraint-transmission systems, an additional adjective has to be used, as in: biological (genetic) language, natural (human) language, formal language, and 2) that the term "language", in all its meanings, encompasses both the symbolic constraints *and* the dynamics that are constrained – the two aspects are inseparable if one is to understand the function of language in a system. This latter consequence heralds an important change from the traditional use of the term 'language' in reference to human language — which, as mentioned earlier, most often indicated only the formal symbolic layer of this human communication system.[4]

Accepting Pattee's general principle of complementarity, too, means agreeing that it does not make sense to talk about symbols without talking about the dynamics that maintain symbolic structures and, on the other hand, are harnessed or controlled by them. In this context, using the term 'language' emphasizes the necessity of rate-independent structures in biological systems – and this, contrary to the contemporary general propensity to describe biological structures in physico-chemical terms, brings attention to the *symbolic side of physical systems*. When addressing the theories of natural language, however, accepting the same principle leads to the emphasis of the *dynamic side of the symbolic system*. In other words, Pattee's view is that particular properties of replicable physical constraints in living organisms make those constraints symbolic, and their system a language. Here, on the contrary — or rather, complementarily — I will underscore that certain properties of symbols in the natural language system make them transmittable physical constraints on dynamics.

Now, obviously, any comparisons between such evolutionarily distant systems as biological heredity and natural languages should be made with caution. Human language is surely a very different phenomenon than other types of informational processes in living

[4] The term „languaging" recently has appeared in the language sciences, adopted from the works of Maturana (1978) see also Cowley, 2012. Its increasingly frequent use may testify to the pressures for including dynamics in our explanations of the human language system.

matter (see also Pattee's commentary for the discussion). Its symbols are certainly elements of a different system, with different properties (e.g., different copying mechanisms) and different forces shaping their structure. To repeat: acknowledging the immensity of differences, I assume, after Pattee, that **an essential feature common to these systems is the specific relation between symbolic and dynamic modes**. In other words, both systems are examples of 'symbols in the wild' forming linguistic systems crucial for natural information processes. And in the case of both one should be careful when assuming equivalence with artificially created, "tame", dynamics-free, formal symbols.

Below I will show that emphasizing the necessity of co-existence of symbols and dynamics in natural language has important theoretical and methodological consequences: On one hand, it gives a new perspective on recurrent problems in linguistic theory, such as: Why is it so notoriously difficult to specify a complete grammar for a language? How can one account for the context-sensitivity of linguistic expressions? How is it possible that natural language is so effective and so flexible? I hope to be able to show that the problems that traditional linguistic theories have with these questions are due to artificially cutting off the symbolic layer of linguistic structures from the natural dynamics that they arose to constrain, and their history in the dynamical system during which they were selected.

On the other hand, however, giving this 'explanatory share' to dynamics obliges the researcher to specify the kinds and time-scales of the relevant processes. This is certainly not an easy task. Studying dynamics requires employing new methods that are designed to deal with complex dynamical systems, and the analysis of the time-course of events, stability, degrees of synergy, type and strength of coupling, etc. This task, I believe is already under way, visible especially in the work on language evolution supported by computer simulations (Steels & Belpaeme, 2005; Smith, Brighton & Kirby, 2003) and in some work in psycholinguistics (MacWhinney, 2005; Rączaszek-Leonardi & Kelso, 2008; Rączaszek-Leonardi, 2010, and others mentioned below). However it is also true that, compared with the influence on research paradigms exerted by the traditional psycholinguistics, this approach is still in its infancy.

2. On coding and meaning: Natural language is not a code

Given that there is a variety of metaphors and comparisons for the workings of genes that use as a source the workings of mental processes (such as memory, code, language) it is important to very carefully and precisely point to the property, proposed here to be shared by genes and languages, that is at the core of informational processes in living systems. Is this core 'linguistic' relation, then, the relation of 'coding'? Shall one talk about the ''genetic language" or ''genetic code"? Or both? And if both, how are they different?

The most intuitive way of drawing an analogy between DNA and language has its basis in understanding natural language as a code — i.e., as a system of forms "standing for" their meanings. Accordingly, certain combinations of nucleotide bases of DNA were seen as standing for certain functions and processes in a cell (or even, before the advent of the epigenetic approach, certain features of a phenotype), just as certain combinations of linguistic signs were seen as standing for certain concepts, sets of semantic features (e.g., Katz and Fodor, 1963), or sets of referents. Such a view of language is possible because of the reification of meaning as something stable, amenable to a static and discrete description (e.g., an intension or extension of a concept corresponding to a word) that can be mapped to another static structure (a sign).[5] It is also congruent with the so called 'conduit metaphor of communication' (Reddy, 1979), i.e. communicating as sending something (signs carrying reified meaning).

While the expression 'genetic code' does not seem controversial, proposing 'language' in the workings of genes has raised doubts (e.g., Oyama, 2000). Yet it seems crucial to note that the common property that Pattee claims to be at the core of informational processes is the specific **relation of symbols to dynamics**. Rather than the relation of *mapping*, that pertains to 'codes', this relation is of constraining, that pertains to generalized 'languages'. It is the constraining relation that is the *meaning* relation. In other words, 'linguistic' in Pattee's sense, does not mean 'code-like', whether in reference to biological or natural language processes. This important distinction may be blurred, because the two relations were understood as being equivalent by many theories: "The view of linguistic communication as achieved by encoding thoughts in sounds is so entrenched in Western culture that it has become hard to see it as a hypothesis rather than a fact" (Sperber and Wilson, 1986, p. 6).

Consider the following example, which posits that a message (chosen by a speaker for linguistically irrelevant reasons) is "*encoded in the form of a phonetic representation of an utterance by means of the system of linguistic rules with which the speaker is equipped. This encoding then becomes a signal to the speaker's articulatory organs, and he vocalizes an utterance of the proper phonetic shape. This is, in turn, picked up by the hearer's auditory organs. The speech sounds that stimulate these organs are then converted into a neural signal from which a phonetic representation equivalent to the one into which the speaker encoded his message is obtained. This representation is decoded into a representation of the same message that the speaker originally chose to convey by the hearer's equivalent system of linguistic rules. Hence, because the hearer employs the same system of rules to decode that the speaker employs to encode, an instance of successful linguistic communication occurs."* (Katz, 1966, p. 103-104).

However, once one takes the Pattee's view (that symbolic structures are constraints on dynamics), it becomes clear that symbolic constraints **do *not* 'map like a code' to the consequences of their actions**. [6] Effects of constraining are naturally context-dependent (crucially relying on the dynamics being constrained), thus are predictable only to some degree -— and, in organisms, are always underdetermined. In natural language too, it is this constraining relation that is the *meaning* relation; and it can arise only from the history of a certain physical structure as a constraint on certain system's dynamics in a certain environment. Such a key property is simply absent from the code-view of language; thus in order to acknowledge the key equivalence of the natural information systems, this view of language has to be abandoned. This has been already recognized by numerous theorists of language, among them those who undermine the apparent simplicity of the relation between form and meaning, grounding it in the dynamics of interaction (Merleau-Ponty, 1960; Cowley & Love, 2006; Kravchenko, 2007).

Now, does this mean eschewing the notion of coding relations entirely from the explanations of natural language or the explanations of information in biological systems?

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[5] The semiotic shift which is based on recognizing that the relations between a sign and its referent is a 3-element relation, i.e., one that includes the interpretant that contextualizes the reference, seems to do part of the job in „uncodifying" the meaning relations.

[6] Pattee calls these constraints 'referents': „The referent of a symbol is an action or constraint that actually functions in the dynamical, real-time sense. Here is where any formal language theory loses contact with real languages." (Pattee, 1980, p. 263?*). However, I will refrain from using the notion of referent, in order to avoid the reification of a symbol's action.

Obviously not. It only means that the relation of 'coding' and the relation of 'meaning' have to be very clearly distinguished. [7] To code is to map one symbolic structure onto another symbolic structure. Meaning is a relation in which a symbolic structure acts to harness dynamics, endowed with this power by the process of natural selection within a given system.

The clear correspondence of the sequence of nucleotide bases to the sequence of amino acids seems to be a good example of a code. So does the correspondence between dots and dashes in a Morse code and letters of alphabet. Both are different from meaning relations, which are based on constraining dynamics in a functional way. In other words, symbols can be coded in another set of symbols, perhaps for a better adaptation to a given transmission medium (e.g., the Morse code is better adapted to a telegraph than the alphabet) but it does not make them more, or less meaningful. A code is not a language. [8] It thus remains an open question as to whether or not the coding relation is at all necessary for a system of symbols to be meaningful. It does not seem so, as long as the system of symbols is itself replicable and capable of variability, and thus can be subjected to natural selection.

Spoken language seems to be just such a system of meaningful replicable constraints: spoken expressions have meaning, as they constrain interpersonal and individual (on-line and ontogenetic) dynamics in a stable, transmittable way. They do not have to be written down in an alphabet in order to mean; nor they are a code themselves — i.e., they do not map onto some kind of internal symbolic structure, a 'mentalese'. Coding processes in natural language include transforming phonological realizations of expressions to written forms, letters of alphabet or ideograms. Such coding is a remedy for the transiency of human speech, an adaptation to a different mode of transmission. Codes can be further coded, as when an alphabet is transformed into a Morse code or Braille. This further changes their potential for transmission, adapting to different media or modalities, but does not change their meaning. Adaptation to transmission media means making the symbolic system more stable under the process of copying (i.e., copying is more accurate), or making the copying process less energy consuming.

Similarly, both the relation of coding and of meaning can be identified in biological informational systems: the "genetic code" is the – stable, fixed – relation of nucleotide bases to amino acids, where the meaning of the symbolic structures of DNA is in the constraining role the proteins have with respect to the cell's dynamics. As Pattee sees it, while the DNA bases code for the amino acids, it is the *folded* amino acid sequence (the protein enzyme) where the first informational constraint on dynamics occurs. „*Folding transforms what are*

[7] It remains to be seen if both can be subsumed by some more general concept — i.e., of a relation that may hold both for mapping between forms *and* being a potential constraint. Perhaps the constraining relations could be treated as a more general concept. Coding would then be seen as a special case of 'superconstraining', to the point of becoming mapping. On the other hand, a very general definition for 'coding' — such as, e.g., used by Barbieri, that coding is setting "*the rules of correspondence between two independent worlds*" (Barbieri, 2003, p. 94), might, somehow, encompass the flexible relations of constraining, making it just another type of code. The latter possibility seems implausible though, given the dynamic and historical nature of the constraining effects. For now, let me set this discussion aside and, for convenience, distinguish between the two types of relations.

[8] Similarly the Braille code: Although numerous petitions arrive at the Braille Authority of North America (mainly from students who would like to count a Braille course towards their second language requirement), the Position Statement of BANA issued in 2008 is: "Braille is not a language but a code." And further: "To call Braille a language would be comparable to calling 'print' a language."

essentially rate-independent syntactically coded sequences into rate-dependent functional controls." (Pattee, 2007, p. 10).

Thus both the *meaning* and the *coding* relations are present in informational systems. Yet it seems that great confusion between them takes place, especially in our explanations about natural language. Linguistic expressions are often seen as forms that "map to meanings"; similarly, some initial theories of heredity proposed that genes map on, code for, or even 'contain' phenotypic traits. In order to effectively 'map' forms to meanings, the events in both domains should be clearly defined and individuated. Doing so is often difficult in the cases of genetic actions and linguistic actions. In natural language, writing is a code for spoken expressions, but it is the spoken expressions that are *the* level at which meaning relation should be sought. In a cell, DNA bases are the code for amino acids, but it is the protein enzymes which interact physically with the dynamics of the cell and which is *the* level at which the function or meaning relation should be sought. Paradoxically, language conceived as a code thus lacks the generalized 'linguistic' property, which is based on symbols constraining dynamics. But below I will show how endowing natural language with the above understanding of symbols, i.e., making it a linguistic system in a generalized sense, provides a framework which opens more productive ways for studying it.

III. Language as a system of selected, replicable constraints

This section shows natural languages as having the essential properties that make them, according to Pattee, carriers of functional constraints. Other work has put emphasis on how to introduce dynamics in the study of language both theoretically (Rączaszek-Leonardi & Kelso, 2008; Thibault, 2004) and empirically (Kelso et al., 1984; Fowler & Saltzman, 1993; Tuller et al., 1994; Cowley, 2004, Shockley et al., 2003, Fusaroli & Tylén, 2012). The importance of the dynamics as a source of language structuring has been also investigated, see e.g., Smith, et al., 2003; Rączaszek-Leonardi, 2009a; Lupyan & Dale, 2010, with the concurrent analysis of the role of psycholinguistic data for the theory of language (Rączaszek-Leonardi, 2009b) and methodology for psycholinguistic research (Rączaszek-Leonardi, 2010). Here, having these developments in mind, I will spell out in a systematic way the reasons why natural language symbols should not be conceptualized as formal symbols. First, the shifts in thinking about symbols described above are applied to natural language symbols. Then the subsequent sections spell out some of the implications of such a turn, which undermines the view of language as an individualistic referential system of arbitrary symbols and points to fruitful ways to study it.

1. Soundwaves with a history

Below, each property listed in I.2 is related to natural language symbols to show the advantages of treating them as replicable constraints.

a. Natural language symbols are physical

"We operate with our own natural language as if it needed no structural basis whatever, and when we speak of other types of symbol systems we usually carryover this unjustified abstraction." (Pattee, 1973, p. 143*).

Pattee rightly points out that the physicality of natural language stimuli is especially prone to be neglected, and therefore seen as inconsequential. The task of designing a theory of the physical realization of linguistic expressions is usually handed down to phonetics, and separated from syntax and semantics – the sciences of structure and meaning. However, without physical instantiation, symbols cannot have any causal powers. The causal power of a word can be acquired only by the participation of its physical realizations in innumerable interactions. In other words, natural language symbols are capable of evoking certain meanings because they participate, as physical stimuli, in various forms of social life. In such social situations, they are strong physical stimuli (most often verbal actions, embedded in other actions) capable of influencing the coordinative situation and modifying it. Among other criteria, it is for the effectiveness and functionality of this modification (for higher-level coordinative aims) that the symbols are selected.

Accepting the view of symbols as constraints makes this physicality stand out. It makes one aware that a physical symbol always co-occurs with, is only a part of, other physical events. Physically, most often, it is a soundwave produced in an interaction, but it is crucial to note that it is a vocal tract gesture that results in a soundwave and that can be apprehended through it (Browman and Goldstein, 1989; Goldstein & Fowler, 2003). The mystery of the causal power of words thus appears less deep: speakers do not act with abstract, immaterial signs. They act with "soundwaves with a history". Now, in order for those soundwaves to have acquired functionality, i.e. to have a meaningful history, they have to be stable and reliable under the laws of physics and principles of perception, and they have to have the power to evoke the desired effect. As I said earlier, the requirements of particular media may make it necessary to code the physical symbolic structures into other physical forms (e.g., writing or a binary code). This however does not make the "original" symbols any less physical.

Thus, what makes a natural language symbol a message, i.e., what makes it different from any other soundwave produced by a human, is that it has been selected and stabilized in the process of cultural evolution; paraphrasing Pattee (1972, p. 249) quoted above, p.6*, these are the "integrated constraints that endow what otherwise would indeed be ordinary [sounds] with their symbolic properties."

b) Natural language symbols are replicable

In order for a physical structure to be selected as a constraint, and to further serve as a memory, it has to be stable enough to be transmitted and its replication should be relatively energetically cheap. This puts conditions on the arbitrariness of linguistic expressions: they are formed according to principles of least production effort and greatest perceptual distinctness (Lindblom et al., 1984; Oudeyer, 2006). These conditions influence both the forms (the phonetic structure of utterances) and their larger structures (e.g. sentence length may be correlated with mean utterance length, constrained by memory requirements; compositional structure may arise under the pressures of learnability (Smith et al., 2003)). The system is thus adapted both to the medium, as well as to the capabilities of the users operating in this medium (Deacon, 1997). Recent research in the emerging field of experimental semiotics shows how the forms and structures of artificially designed symbol systems for collaboration are structured by various demands and properties of the medium (Fay et al., 2010; Galantucci, Kroos and Rhodes, 2010).

c) Symbols are selected constraints

As noted in (a), above, what makes physical stimuli the carriers of constraints is their history in the system. In natural language, this history involves processes on several time-scales: a structure is selected for bringing about a particular effect (here and now; for interaction or an individual) and for being transmittable (both here and now: heard, perceived; and in ontogeny: learned). In the cultural time-scale processes that maintain the coherence of the linguistic systems, the compatibility and relevance of the constraints brought by a structure with respect to other structures are decisive. The form and structure of expressions of natural language are thus shaped by these multiple selective forces. In this context, studies of the structural properties of symbols in natural language should include both the diachronic analyses of the use of language and the data on language development and learning (Tabor, 1994; Lupyan & Dale, 2010; Smith, et al., 2003). Also, it is important to remember that for selection to occur, variability is needed. The awareness of these facts makes a researcher look differently at the so-called "nonstandard" uses of language. Rather than imperfections of processing, they are seen as variations necessary for the plasticity of a system (Steels, 2006), which "seeks" to find a better fit to the coordination goals in the process of cultural evolution. Non-standard uses can thus be seen not only as errors (which obviously occur), but also as constantly "trying on" new structures for various coordinative functions. Obviously, the fact that linguistic symbols are physical structures immersed in many other processes is not something that a speaker needs to be aware of. On the contrary: it may well be that the phenomenal experience of a symbol's stability, and even, perhaps, that of a clear reference, is needed for it to perform a coordinative function.

d) Linguistic expressions are constraints that harness dynamics.

Meaning arises only through the behaviour of constrained dynamics. Linguistic symbols do not "carry", or "transfer" meaning. Seen from this perspective, symbols of natural language do not map to or "represent" the external world; the meaning, or what might be just an element constituting 'meaning' in such a complex view, rests in how they are able to change the existing dynamics of a system composed of interacting individuals. Again, this is far from a code-view of language. Thus, both harnessing individual cognitive dynamics and constraining the dynamics of ongoing interaction constitute the meaning of linguistic expressions. Even if effects for the cognition of an individual are often seen as being of primary importance (e.g., Chomsky, 2011), the harnessing power is gained in the processes of selection and one of the most important selection criteria for a structure is its **effectiveness in inter-individual coordination**. The conviction about the primacy of this social-coordinative function of language is obviously not a novelty: "*(...) each higher function initially had been a particular form of social collaboration and only later it transformed into individual behaviour, interiorizing structures (...).*" (Vygotsky, 1930/2006, p. 62), the transformation being due to internalizing language.

Therefore it would be difficult to maintain that meaning can be found in conceptual/semantic networks of individual minds or in objects in the external world. Meaning is what an expression does in a situation. Such an approach turns language investigations in the direction of functionally and pragmatically oriented theories of language. The structuralist and poststructuralist methodology of looking at the superficial systematicities of the selected forms will tell us close to nothing about how the structures arose and therefore what they might do in various situations. As can be inferred from the above discussion, proposing a generative machinery in the language user's mind also will not do the job. Studying only the symbolic mode of natural language makes little sense without a complementary study of dynamics in which the symbols are immersed.

Thus, the study of language should be the study of forms in their function of constraining dynamics. Reliance on dynamics gives the utterances context-sensitivity for free: the utterances are (almost) always contextually relevant, simply because context (the existing dynamics) is always an essential part of the meaning (Rączaszek-Leonardi & Kelso, 2008). Symbols contribute only how dynamics is to be constrained. This also explains the effectiveness of language, i.e., the fact that the same expression may mean infinitely many things, depending on the context (e.g., Barwise and Perry, 1983), i.e. on the dynamics in which it is immersed.

If we agree that symbols do not carry meanings by themselves, then instead of thinking that the symbol's meaning is disambiguated by situation and previous expressions, we can say that it is rather an utterance that directs the fate of an interaction and thus chooses one of its many possible developments, a path which will be taken by a system of conversing people. In this approach, the common ground, understood as shared dynamics (physical as well as cognitive) is already present in each interaction and further shaped and stabilized by language. Instead of being a background against which symbols are exchanged, such common ground is an essential part, a substrate of meaning to which symbols bring only small "pushes" by making it functional in a situation. Looking at linguistic interaction without the 'written language bias' (Linell, 2007) reveals that language does not constitute interactions but rather constrains existing ones — in accordance with the view that a "*good biological as well as good engineering design makes the maximum use of natural (non-informational) constraints and laws of nature, so that the control information can be kept to a minimum*" (Pattee, 1982a). Such principles of reliance on the inherent dynamics of a system, with external constraints providing "only" a functional binding of the degrees of freedom of a system, have been already used in behavioural sciences, e.g. at the level of motor control (Bernstein, 1967).

Including the dynamics as an essential element of explanation, takes the explanatory burden off the linguistic structures, but, on the other hand, obliges researchers to identify the time-scales and systems in which the relevant dynamical events unfold. This means going back form studying mainly written language or grammaticality judgments of single sentences to the real-life linguistic interactions (Schegloff, Ochs, Thompson, 1996). With the possibilities of the data gathering and analysis we have now, it becomes feasible to see utterances as a part of on-going interactions, analyzing these on the pico-scale level (Steffensen & Cowley, 2010) but also tracing the interaction dynamics, both on the level of physical movements (Shockley et al., 2003), patterns of linguistic exchange (Orsucci, et al., 2006; Fusaroli and Tylén, 2012), as well as more cognitive alignments.

Such a perspective connects the studies of language structure and function with both the study of embodied cognition and studies of joint action. Emergence, nature and the role of linguistic (or other symbolic, e.g. diagrammatic) communication in various task settings leads to a better understanding of the collective performance and development of common ground, through the systematic, mutual informational constraining that occurs in linguistic exchange; what happens is the selection of only certain aspects of a situation and, at the same time, stabilization of the successful symbolic patterns (Fusaroli & Tylén, 2012, Galantucci, 2005; Fay et al., 2010). Besides the already mentioned studies in experimental semiotics (Galantucci & Sebanz (2009)), established methods such as conversational analysis are becoming particularly useful since they are designed for the study of language in its natural 'habitat', in connection with the culturally specific social forms of life that take place at the moment (Schegloff et al., 1996; Zinken & Ogiermann, 2011).

e) Communication has a coordinative role

If we accept that symbols are selected constraints on dynamics — in other words, that they effectuate a functional reduction of the degrees of freedom of a system — in the case of natural language the coordinative function comes to the fore (see Rączaszek-Leonardi, 2009a). Language lives in the interaction between and among people, thus the dynamics the symbols harness concern, above all, the dynamics of interaction. Since it is the interaction that becomes the functional system, communicative processes are thus not to be understood in terms of transmitting information, i.e., the "conduit metaphor" (Reddy, 1979), in which symbols "stand for" references and thus have a power of evoking in a hearer *the same* referent that is meant by a speaker. Rather, the alternating use of symbols by participants steers the interaction as a whole through the possible state space, by constraining parts of this system in an appropriate (functional) way.

Interaction may well be the most important level at which the efficiency of symbols is "evaluated" – i.e., the effectiveness of the coordination in interaction might be the most important criterion for the selection of symbolic structures. Contrary to our phenomenal experience of mastering language as individuals, language is thus a distributed system, created by populations to exercise adaptive forms of coordination of its members. Meaning, in this picture, is co-created in participation by interlocutors (de Jaegher and di Paolo, 2007).

A striking consequence of this view is that if individual 'meaning' is understood as the individual cognitive system dynamics constrained by a given symbolic structure in a given situation — i.e., the dynamical process in an individual brain evoked by a symbolic structure — then it is necessarily different for every individual. It is influenced by a personal history of the use of a given expression and an individual conceptual landscape. This challenges theories of linguistic meaning, which assume (congruently with the "conduit metaphor" of communication, the "code" metaphor for language, or the "container metaphor" of a symbol) that a symbol carries invariant meaning from a speaker to a hearer.

If, on the other hand, expressions of natural language are seen as replicable constraints on interpersonal dynamics, functional to co-action in the environment, the differences in individuals' brain dynamics that are constrained by a symbol do not pose a problem. On the contrary, for all we know, for certain coordinative purposes it might be better to have individuals with slightly different "meanings" for an item, perhaps covering a larger ground for possible joint interpretations, and/or complementing each other in a given coordinative task (Rączaszek-Leonardi & Cowley, 2012). In such populations of "differently minded" agents, the adaptation to a changing environment might be quicker than it would be in uniform, homogeneous ones, similarly to what we see in artificial classification systems using, ensemble computing, i.e., engaging agents with different algorithms.

It is true that coordinating individual physical or cognitive efforts in a situation in most cases includes agreeing on what objects in the external world the coordinated action would involve. But agreeing on reference is neither a sufficient nor a necessary condition for interpersonal coordination through language, the simplest example being the realization of the phatic function of speech (Malinowski, 1981). Thus, if language is seen as a system of transmittable constraints on dynamics, it can hardly be expected that it somehow mirrors, or reflects, the external world. Any 'picture' of the world's external structure detected in language will be filtered through the necessity of co-action in the world. More in the vein of Wittgenstein's language games (Wittgenstein, 1953, theses 23, 241), utterances are selected as forms of life within a community (see also Goodwin, 2000, Zinken, 2008). They constrain existing dynamics of the participants, which includes coordination dynamics. It thus becomes crucial to identify the existing coordination in order to see how language constrains it further.

What does this mean for natural language research? Studying the harnessing (and thus enabling) role of language requires, as we said earlier, identifying the dynamics that are harnessed. This is not easy: the dynamics concern many different time-scales and systems (or levels) (Rączaszek-Leonardi, 2009a). One of the types of dynamics is the physical and cognitive dynamics of interaction in joint action and/or joint problem solving. This links the study of language to the studies of these phenomena. Studies of human interpersonal motor coordination have been conducted at least since the 80s. They show powerful mechanisms for stabilizing the modes of synchronization in humans (Schmidt, Carello & Turvey, 1990; Richardson et al., 2007), as well as principles for creating functional co-action systems in the face of a common task (Schmidt & Richardson, 2008; Marsh et al., 2006). Linguistic interaction has its own, specific physical coordination background, with synchronized movements and imitative actions (Shockley, et al., 2003; Pickering & Garrod, 2004). Neural bases for joint action are also the topic of recent research, with the findings on mirror neurons interpreted in terms of complementary rather than imitative actions (van Schie, et al., 2008;

Sartori et al., 2011). The study of linguistic interaction becomes a study of how the existing modes of interaction are modified by language, becoming more effective and culturally specific.

f) **Degree of constraint** provides a useful dimension for characterizing expressions in terms of the role of context in determining their meaning. As we pointed out before, seeing linguistic symbols as constraints makes them naturally both context-sensitive and effective (applicable) in different contexts. Constraining, depending on the role and cultural history of an expression may be strong (as in the case of 'hydrogen peroxide'; or other scientific terms, which if given precise definitions may approach the formal languages' context-independence), weaker (as in the case of the word "dog") or very weak (as in the case of the word "here"). In natural talk, some play is always left for the natural dynamics of interaction among persons in a particular context or environment that determines the actual, realized meaning.

These features are incongruent with the picture of language as an individually represented system of arbitrary, referential symbols. Language is seen instead as a means of inter-individual coordination, its expressions serve as doing rather than referring, and the arbitrariness of linguistic symbols seems to be much more limited than usually thought. Let me elaborate on these points.

2. Controlled collectivity

As already noted above, accepting the coordinating role of language, changes the level that is seen as the most crucial source of selection criteria for symbolic structures. The quality of interaction in the environment, not a single action, comes to the fore. In the light of this "primacy of 'we'", the background assumed for the effective action of symbols is thus not the individual knowledge needed for understanding, but rather, the shared physical and cognitive dynamics of an already on-going interaction. The interaction, as potently shown by the work of di Paolo and his colleagues, assumes an important ontological and thus explanatory status (di Paolo et al., 2008). Certain individual traits or behaviours are simply not explainable at the level of individual cognitive processes – they appear only as a consequence of being in interaction; they are created in interaction. As pointed out in Rączaszek-Leonardi & Cowley, 2012, this insight may be a step toward answering difficult questions regarding the possibility of on-line intersubjective states, joint attention, and shared goals — paraphrasing William James' view on the nature of emotions: we do not interact because we have a shared cognitive or/and emotional state, but rather we have a shared cognitive or emotional state because we interact.

This basic interactivity relies on low level, swarm-like mechanisms of interaction, which are shown, e.g., in the latest research on joint action (Richardson et al., 2010), coordination in conversation, and readiness for complementary actions (see e.g. van Schie et al., 2008; Sartori et al., 2011). Such interactivity can be linked to distinct neural markers in individual brain activation patterns – such as the *phi*-complex (Tognoli et al., 2007). Applied to language, this shows the importance of both physical and cognitive coordination in the conceptualization of what "common ground" may consist of. When common ground is understood as shared dynamics, the richness of meaning evoked by linguistic expressions and, on the other hand, their contextuality, ceases to be a challenge. Admittedly, however, such a view does present new difficulties: i) it makes abstract linguistic analyses difficult because one never knows what is communicated unless one knows what was shared; ii) it imposes on a researcher the requirement to identify the many kinds of relevant dynamics. Turning again to the positive side, the view presented here may support the emerging framework for encompassing these diverse factors and point to the methods for providing data about them.

3. Referential properties of linguistic symbols

Accepting points d) and e) above, which entails viewing the role of symbols as harnessing dynamics that leads to functional reduction of a system's degrees of freedom, underscores the coordinative role of language. This brings new perspectives on referential properties of language and a broader question of the possibility of cognition through language. Since elements of language in many philosophical and linguistic theories are thought to clearly correspond to objects in the world, sentences are seen as statements about these objects. Thus their meaning, casted in truth-conditional terms, corresponds to the configuration of states of the world.

Seeing language as primarily a tool for social coordination does not, obviously, eliminate the referential aspect of language. After all, coordination in most cases has to be *about* some aspects of the external world if it is to lead to the (jointly effectuated) changes in the environment. Establishing joint attention, identifying objects of joint action and joint cognition is crucial to such effectuation. However, the referential aspect is secondary to coordination and important in only some aspects of communication. What is more, reference in coordination situations, although preserving the physical identity of an object in a real physical interaction, may actually require inter-individual differences in 'intension', as explained in point III.1.e.

How the issue of reference relates to the meanings of natural language symbols that, in this framework, are defined by the effects on various kinds of dynamics, is a fascinating and complicated problem. What seems to be clear from this perspective is that the ways in which reference and joint reference are achieved in language should be studied by investigating the pragmatic aspects of language use (Hanna et al., 2003; Dale et al., 2011), rather than by investigating the system by itself and assuming obvious referential properties of symbols. Investigating the integration of the constraining function, achieved through repetitive use and selection, can help uncover the referential role, which is always mediated through the coordinative role of language. Moreover, a possibility should be always kept open that the individual feeling of 'grasping' a concrete, reified meaning of an expression may be subservient to the overall coordination goal of an expression, putting the "direct perception of meaning" in a broader perspective of socially interactive coordination.

From this perspective, grammatically formed sentence, seen as a statement about the world, does not serve as an atom of meaning; rather, units of meaning would be distinguished on more pragmatic grounds. On the time-scale of interaction these would be acts of coordination, in which linguistic expressions play the controlling role. Motivated by coordination effectiveness, selective pressures will act on words, constructions, phrases, depending on how they enter interactive activity. Thus, in the words of Schegloff, "the interactional matrix of grammar requires a different understanding of what should enter into a linguistic description and/or a different model of linguistic structure" (Schegloff et al. 1996: 24).

4. Conditions on arbitrariness

There is an obvious arbitrariness to the selection of a particular physical structure to become a constraint. But the crucial "contacts" that symbolic structures have with dynamical processes impose at least two kinds of limits: 1) the initial limits on arbitrariness: not any structure could have become a specific constraint; only the ones that actually can enter in a causal relationship with a constrained process, and those that can be reliably copied with minimal effort (an argument for this kind of non-arbitrariness would be the universality of the genetic code, as Pattee (1969) notes); and 2) historical limits on arbitrariness: since selection, acting on the level of phenotype, occurs by virtue of a particular physical structure harnessing the dynamics in a specific way, the history of these choices is crucial for the symbol structure's meaning. It cannot be arbitrarily swapped with a different structure that does not have this history.

Thus constraints, being physical structures themselves, in order to be good functional constraints harnessing the right kind of dynamics in a right way, must have the following properties: i) they must have the potential of acting on the dynamics, ii) they must have been selected on the basis of acting on the dynamics within a system of other constraints, and iii) they must be reproducible in a reliable way by whatever mechanism there is to reproduce them. These factors will limit the form and the structure of the symbol system in a living organism.

The claim about arbitrariness, i.e., that the choice of a word is not determined by its meaning (referent) has been an important element of natural language theories (e.g., de Saussure, 1916/1983). Hockett (1960) considered it to be one of the defining features of language, and the idea of this independence is in an intuitive way supported by the often quoted fact that names of the same things are different in deferent languages, or by the existence of polysemy and homonymy in language. [9] Obviously it was recognized, even by de Saussure himself, that arbitrariness is limited: a sign has to be phonologically plausible in a given language, and the free variation of signs is checked by historical and social factors (Chandler, 1995). "As Lévi-Strauss noted, the sign is arbitrary *a priori* but ceases to be arbitrary *a posteriori* - after the sign has come into historical existence it cannot be arbitrarily changed (Lévi-Strauss 1972, 91)." Thus "(…) every sign acquires a history and connotations of its own which are familiar to members of the sign-users' culture." (Chandler, 1995). The latter process is often seen as "conventionalization".

In a picture of language in which dynamics is always present, and in which symbolic structures are the outcome of selection on the basis of the effectiveness of constraining the dynamics and their transmittability, the types of limits to arbitrariness can be shown more clearly. Each one of the relevant dynamics will exert its pressures on the symbolic forms and the shape of their structures (Rączaszek-Leonardi, 2009a). Forms have to be easily reproducible, with a good ratio of perceptual distinguishability to production costs (Lindblom et al., 1984); structures must be learnable, i.e., adapted to cognitive skills of a child (Deacon, 1997), and, on the on-line interaction time-scale structures of symbols are obviously shaped by the structure of constraints they – together - impose. Such factors, and others, act as a set of strong and weak pressures and selection biases in the cultural evolution of language (for an example of such possible biases in grammatical gender assignment, see Rączaszek-Leonardi, 2010). Any particular form we encounter in a language is the outcome of these historical, selective processes. What is more, forms are "alive" — they are, in any moment, in contact with the dynamics that upholds the system and that may be responsible for changes (Steels, 2006). Yet all of this is unexpected, if one looks just at the structure.

Moreover, in this picture it is easier to see how the process of conventionalization may occur. Conventionalization does not happen by an act of conventionalizing, but rather, by the spreading and the selection of forms in multiple interactions. Expressions that prove functional in an on-line interaction are stabilized (see e.g. Tylén and Fusaroli, 2011), and, if they sustain learnability requirements, spread as culturally-specific controls on co-action, sharpening their function in multiple social episodes (Zinken & Ogiermann, 2011).

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[9] A good introduction to the issue of arbitrariness in language can be found in Chandler, 1995.

Arbitrariness, obviously, is still a feature of languages, but the claim about its degree becomes much more qualified here than in the code-view of language (see also Zinken, submitted)

I hope to have shown above, that the understanding of the notion of a "symbol" proposed here, and the view on the relation that such symbols have to the dynamics of a system within which they evolve, when applied to natural language, leads to a change of several important assumptions that many take for granted. This may result in new ways of thinking about linguistic phenomena and give a more convenient framework for studying language as a dynamical system, unfolding on several time-scales and encompassing several levels of organization. This framework not only finds a place for phenomena that were not easily accounted for in previous approaches (e.g., the efficiency of language, its context dependency, coordinative nature) but also makes applicable the tools created for dealing with the said complexity: namely, the mathematical tools developed to study non-linear complex dynamics in physics. Such a perspective opens up many new dimensions on which to analyze language phenomena, such as stability, temporal coherence, dimensionality, and degree of coordination. At the same time, it is very important to note, that unlike the strictly dynamical approaches, it does not eschew the symbolic description form the explanation, nor assign it merely an auxiliary, epiphenomenal role. Symbolic structures are essential entities in this explanatory scheme, but are not understandable without their complementary dynamical description.

Claiming that the core nature of 'being a transmittable constraint on dynamics' is the same for biological and cultural systems brings a drastic change in the analysis of the latter, but it does not obscure the profound differences between the systems. Enumerating them is beyond the scope of this paper and, perhaps, not a sensible task in general. After all, these are very different systems that arose to constrain very different processes. Some of the important differences are described in Pattee's commentary in this volume. Others can be inferred from considering the above characteristics of symbols in biological and linguistic systems (such as emphasizing the inter-agent level of coordination in linguistic systems rather than the within-agent one). As pointed out above, considering natural language as an instance of more general informational system ushers in new dimensions on which it can be analyzed and studied. In particular, the structure of the symbolic mode is now seen as forming under multiple pressures that are specific to humans and their communication systems, thus allowing the integration of the subfields of the psychology of language in interesting and productive ways, and connecting it to other domains, such as evolution of communication, sociolinguistics or anthropology. Against this background, too, particularities of concrete systems stand out more clearly and their implications can thus be better analyzed.

5. Example of a difference: Fast replication of un-coded forms

Attention to the mechanism of spreading of symbolic forms reveals the uniqueness of natural language. The non-hereditary, learning-based "replication" of linguistic structures puts the learning capacities of an individual at the center of psycholinguistic interests. Seeing these capacities as preconditions for an easy spreading of effective constraints creates a conceptual place within a bigger framework for the abilities of statistical learning, and rule formation which undoubtedly is one of the individual cognitive endowments essential for language. On the other hand, transmission of language through learning in ontogenesis is not just spreading by copying (as in the case of written language) or spreading by reproducing structure by a theoretical innate machine inside a child's head. For, aside from imitation and the statistical learning of the form, the ontogenetic processes of language learning include situated learning in which a child experiences words in action and can then try out their power in interaction. Focusing on such phenomena brings about the possibility of experimenting with, and observing the immediate effects of, the ways in which children develop a certain attitude towards language (that Cowley calls the ‘language stance’ (Cowley, 2011)), the adoption of which may drastically shorten the scale of structure selection and stabilization, as well as introduce new sources for variation and complexity.

Thus, variation and selection in biological systems proceed according to a generational clock, while human language changes on a much shorter time-scale: that of cultural evolution. The individual processes through which a person, in numerous interactions, learns multiple ways of a symbol’s use and has it at her disposal at the moment of production is also a source of the voluntary variability in language — i.e., innovation, which rests on the ability to use it creatively ‘with sense’, that works alongside random variation to propose new ways of control on dynamics.

With this paper, I hope to have shown the way in which language sciences can be transformed by changing their fundamental assumptions about the nature of language and its symbols. Some of these transformations are already taking place (as I pointed out above, mentioning the growing body of research on the dynamical factors shaping language structure as well as the research on on-line language use in real interactions), albeit without the explicit re-definition of symbols. I have merely outlined the fundamental shifts in symbol/dynamics relations, and did not explicitly address many factors crucial for the new theory of language entailed by it. Such details concern both the “dynamical side” (the question, for example, of how it happens that social and emotional coordination can be value-instilling, and what role language plays in this process (see e.g., Trevarthen & Aitken, 2001; Cowley, 2004; Hodges, 2007)) and the “symbolic side” which requires an in-depth examination of the “individual machinery” needed for correct and creative language use which certainly depends also on statistical learning and rule discovery.

The goal in this paper was only to show that such factors *can* be investigated within one framework — one which acknowledges that individual language ‘processing’ is *never* separated from ongoing interpersonal and individual dynamics, and that linking to these dynamics happened through historical, selective events. These dynamics co-constitute the ‘meaning’ of what is said and can *always* be the cause of rule breaking, creativity and flexibility. In other words, what I hoped to have shown here is that incorporating some of Howard Pattee’s key insights into the study of language can result in a framework in which symbol-concentrated, structuralist analysis may find its place alongside the investigations of the dynamic forces. Giving up some long-cherished assumptions about the nature of symbols in natural language, in other words, may well be worth it. What’s more, this potential for reconciliation is not limited to the natural language phenomenon, but may apply to the nature of cognition in general.

IV. Further Along the Third Path of Complementarity

While Pattee has investigated the necessity of complementary models mostly at the level of genetic information in living organisms, he also recognizes it as a general principle — one that pertains to the symbol-matter or mind-body problem in general. Below I briefly sketch the history of this problem in modern cognitive science, which will constitute the background for my arguing for the value of Pattee's approach as a "third way". I will reflect on its viability towards solutions of these more general problems as well as on possible reasons why it is still not accepted by many. Finally, while agreeing that conceptually and theoretically this seems to be a promising direction, I point out that there are inherent difficulties in characterizing the brain's memory structures in terms of symbolic constraints. Two possible ways of looking at this problem will be discussed. And finally, I will end with an examination of the role of language as the external, culturally molded system of constraints on individual cognition — i.e., the workings of the mind.

1. "Symbolic" vs. "dynamic" in cognitive science

As most cognitivists agree, the excitement of shaping the new approach to human cognition in the 1950s stemmed from, among other factors, the possibility of modeling cognitive processes in artificial intelligent systems. In many cases, this assumed the compatibility of human cognition with computational devices. Perhaps the most powerful statement of this analogy was the Turing formalism, which showed that all computation can be realized by a universal machine. As noted earlier, this led to the assumption that symbols in the human mind and computational symbols in a computer can be treated as equivalent. Quite soon, however, the theorists of cognition realized that the symbols in such formal models of thinking remain 'ungrounded', and that it was not easy to specify who or what in the system could interpret the symbols – i.e., give them meaning — and how.

The most renowned critique came in the form of John Searle's Chinese Room argument, in which he addressed the insufficiency of syntactic rules for specifying semantics (Searle, 1980, 1986). Similar under-specification of semantics within a formal model of mind was pointed out by Harnad (1990) in his famous paper *The Symbol Grounding Problem*. The conclusion of both works is that the interpretation of symbols, giving them meaning, requires "a loan on intelligence" (Kelso, 1995), not unlike the one that behaviorists had to repay for exorcising mental states from the explanation of behavior (see Dennett, 1978, who originally used the phrase).

As Pattee writes in his commentary to this volume, Newell and Simon's Physical Systems Hypothesis, once proposed as the new framework for emerging cognitive sciences, did not provide any way to link the dynamics of physical laws to the non-dynamic symbol vehicles — thus, the behavior of dynamic matter was actually not thought to constitute an element of functional explanations. Cognitive systems were supposed to be realizable on many different 'machines' and computations were supposed to be realized in error-free environments, usually containing no novelty (Pattee, this volume, p. 18*).

It is important to note that what was considered to be cognitive, intelligent behavior was, in these early days of cognitive psychology and cognitive science, limited to what some would call "higher cognition", and included, above all, activities such as problem solving, conducting mathematical proofs (e.g., The General Problem Solver of Newell and Simon), reasoning, decision-making and language processing. However after the advancement of first theories of perception and pattern recognition in this framework, and the attempts to account for so-called 'lower cognition' (such as, navigating one's environment, skill acquisition, non-linguistic memory, or coordinated action) it quickly became evident that in these domains the symbol-based "information processing" was not as useful or convenient. It is primarily due to research into these range of problems that an alternative view of cognition at that time flourished, giving rise to 'ecological psychology', consolidated by the research and theoretical writings of James Gibson (e.g., 1951, 1960, 1961, 1966) and subsequently continued in the Haskins Laboratories at the University of Connecticut by the Turvey group, and the Center for Complex Systems and Brain Sciences established by Scott Kelso.

The ecological psychology school stood in opposition to the information processing approach; opting for the "direct perception" of the environment, possible because of the evolutionarily "tuned-in" senses (Gibson, 1966), and perception-action coupling, rather than the primacy of symbol-driven computationalism. The approach deemed mental symbol processing unnecessary for intelligent behavior, and eschewed "symbolic mental representations", even when it came to processes that seemed to clearly require them, such as memory (Freeman and Skarda, 1990). Models based on dynamics, self-organization, and local responsiveness to the environmental input could indeed account for quite an impressive range of psychological phenomena, such as speech perception and production (Kelso et al., 1984; Tuller, et al., 1994; Fowler & Saltzman, 1993), motor coordination and motor learning (Kelso, et al., 1990; Kelso, 1995, Schöner & Kelso, 1988; Schöner et al., 1992), and inter-individual coordination (Turvey, 1990), at the same time becoming the foundation for novel approaches to creating artificial intelligent systems (Brooks, 1991).

On the other hand, the approach was criticized for being inapplicable to the problems in higher cognition that most psychologists were interested in. Although attempts were made to make the notion of 'symbol' compatible with the Gibsonian approach (see e.g., Greeno, 1994), it was not clear what their ontological status would be and how they would be realized, incorporated by the workings into the dynamical perception-action system.

One of the first to advocate the reconciliation of the two schools was Ulric Neissser, who already in 1976 admitted his disappointment with the information-processing approach, and emphasized instead the merits of ecological psychology of perception. Later (e.g., Neisser, 1994), he proposed that the way to this reconciliation would be a view of cognition as a polymorphic system, in which subsystems are responsible for dealing with specific kinds of cognitive tasks. He distinguished between direct perception, representation and recognition and the social, interpersonal sensitivity subsystems, which in higher cognitive functions come to work together.

Insightful and bold as it was, not even this approach offered a way to join symbols with dynamics; Neisser expressed a hope that the emerging connectionist approach might prove capable of integrating the models. At the end of the 1980s, with the revival of the connectionist (artificial neural networks) school, it seemed indeed that some kind of reconciliation would be possible. Neural networks were, essentially, dynamical systems, and were proposed to encompass symbolic functioning either on a sub-symbolic level (Smolensky, 1988), or by associating stable 'labels' represented on a set of units (e.g., Kawamoto, 1993). However, it was still not clear how such 'symbols' would acquire their special status (if they have one) and how, in an artificial net, their action would be different from any other input action. Some hopes arose again with the advances in hybrid modeling (ACT-R, CLARION) (McClelland, 2009), which, however, were criticized for being excessively modular and most often more focused on dividing the tasks to be sent to particular modules, than in specifying the ways in which symbolic and dynamic procedures could cooperate.

The increasing popularity of such models testifies to the search for integration, which may mean that specifying the relation between symbols and dynamics in theories of behaviour and cognition becomes important for a growing number of researchers. This makes one think that it is the right time for embracing an approach which long ago proposed a way for specifying this very relation.

2. ‘Symbolic’ *with* ‘dynamic’ in cognitive science

In the light of the above, it is curious that the one approach that never decoupled symbols from dynamics was not welcomed immediately. As I suggested earlier, one possible reason was the magnetic promise of easy modeling of apparently symbolic mental processes by computational systems that strengthened the analogy and, in general, the computer metaphor of the brain. Mental ‘symbols’ were thus taken to *be* formal symbols, i.e., symbols with ‘maximally harnessed dynamics’. Because of this assumption, one finds the neglect of the self-reconstruction requirement of von Neumann, the sinking to near oblivion of such works as Polanyi’s (1968), and the attention to Turing’s ideas on the universality of computation, rather than his other work, such as the work on morphogenesis. Anther reason for the reluctance to accept that complementary models might be necessary to deal with cognitive phenomena is the Occam’s razor-like conviction that one model is always better than two, which favors reductionism (see also Pattee’s commentary, p.*). And yet another is that if material dynamics are considered important for informational processes then one needs tools for studying and description of these dynamics – and the majority of these tools had not then been developed.

The complexity is indeed mind-boggling. As I showed earlier in this paper (and in more detail elsewhere (Rączaszek-Leonardi, 2009a)), timescales of relevant dynamics for cognitive process (e.g., for natural language) range from milliseconds of brain activity, to seconds and minutes of on-line interactions, to months and years of developmental processes, to hundreds years of cultural evolution, while the mutually dependent systems that operate within these time-scales include individual brains, dyads, groups and populations. Only recently have we developed mathematical tools sophisticated enough to deal with the complexity in physics and computational powers necessary for creating good models of complex phenomena. It should be pointed out that many such models in the domain of behavioural sciences were developed within the ecological psychology approach (Jeka & Kelso, 1989; Schöner, G., & Kelso, 1988; Kelso, 1995; Turvey, 1990; Turvey, van Orden & Holden, 2003).

With the conception that the symbolic level is necessary to describe selected constraints on dynamics, which makes such symbols functional, Pattee shows that the approaches represented by the information processing approach and the ecological psychology construct complementary models of cognitive processes, of which neither can function independently.

> “*I am not opposing the ecological attitude elaborated by Fowler and Turvey, nor am I supporting it in opposition to the information processing approaches. I am claiming that these are two complementary modes of description that have not yet been completely articulated and, more fundamentally, have not been recognized as essentially complementary, in the sense that any explanation of cognitive behavior will require both modes of description.*” Pattee, 1982, p. 22

If the dynamics on multiple timescales is not taken into account, this means that explanation is fixated upon only a slice of dynamical process at some point of time, showing only synchronic relations; this attitude is similar to the reluctance of structural linguistics to talk about diachrony. The fact that a symbol is a physical outcome of selective processes is conveniently omitted. Stripping symbols from their history in a given dynamics entails the simplification of the system, even if it may enable a more close-up examination of their structures.

The symbolic model is thus a way of framing, generalizing, and assuming approximation of the dynamical history and agreeing that the functional framework will be external to the system. It makes sense only if one remembers such structure's dynamical provenience, which, in turn, entails that sometimes a natural symbol within its structure will not behave like a formal symbol would. The dynamic model, on the other hand, gives the account of the substrate of the symbol's controlling action – which is difficult, because often it is taken for granted. Recent rapid developments in the theory of embodiment of cognition is a sign that increasingly more attention is given to natural dynamics of the bodily interaction with environment and with others.

3. Complementarity of the brain models

According to the ideas laid out in the papers in this volume, preserving functional organization requires passing constraints from one moment in time to another. In the case of such 'memories' in the brain – shall they also be seen as symbolic structures? If yes, what form could the local symbolic constraints take in this case? As Peter Cariani asks (2001, p. 3): "*What does it mean to say that neurons perform 'computations' or 'measurements' or that 'symbols' exist in the brain?*"

There are certainly many attempts to answer this question, and the summary of them is beyond the scope of this paper. In the light of the approach presented above, two ways of proceeding are perhaps most interesting: (a) looking for candidates for the replicable constraints in the brain or, (b) following, e.g., Freeman's proposal (Freeman & Skarda, 1990; Freeman, 1995) 'leaving' the workings on the brain to the dynamical level that, being a part of a broader system, relies on externally manufactured structures for functional transmittable constraints. Let me elaborate these possibilities.

(a) Since the brain is capable of a continuous "regeneration of informational order" (Cariani, 2001), internal constraints on dynamics must exist that serve the communication of adaptive states from one moment to another (i.e., the communication of the brain at one moment with itself at the next moment). The quest for such structures is thus open: "*The current situation in the neurosciences regarding the neural code is not unlike the situation in molecular biology before the elucidation of the genetic code*." (Cariani, 2001) Such a code, or rather, as I noted earlier, such a *language*, should explain the informational self-reconstruction and epistemic operations of the brain. Thus, the search for reproducible patterns of neuronal activity able to function as constraints.

Among the most important consequences of understanding symbolic structures as physical structures that act as constraints on dynamics is, as I pointed out earlier, that these physical structures might have a very different form in different systems (e.g., a reproducible nucleotide base or an articulatory gesture producing a soundwave in natural language) and that the constraining action is not of an all-or-none type but is a matter of a degree. In some cases (as in the case of computing devices) the harnessing is strong, to the point of not leaving any 'play' to natural dynamics; in others, as in the case of the gene setting off an avalanche of dynamical events, it is just a push in the right (evolutionarily selected) direction. If the brain's memory structures can indeed be conceptualized as transmittable constraints on dynamics, then one would expect both that symbolic structures are less discrete than in the more well known symbol systems — yet still reproducible! — and that the harnessing is certainly less severe than in the case of a formal symbol. Many kinds of memory, however, can probably be explained in a Gibsonian way, as a modification of direct perception-action coupling, which leads us to the second, equally controversial, possibility:

(b) The brain does not need internal transmittable constraints, but rather relies on the external ones. Counterintuitively, the brain's ability to think symbolically would be then linked to the ability to produce external physical signs: "*Not pure ideas in pure consciousness, but concrete signs lie at the base, signs which are for us recognizable and reproducible* *despite small variations in detailed execution, signs which by and large we know how to handle.*" Weyl (1949), quoted in Cariani (2001).

Within such an approach, brains are seen as parts of larger systems, together with the physical environment and other brains, with symbols constructed for social, coordinative purposes (Freeman, 1995), and constituting a new cognitive niche (Clark, 2006). Such a view seems congruent with Pattee's observation that: "*Until the production of the discrete symbolic expression, there is no simple concept or measure of the 'information in the brain*'". p. 226 (2006). The general view of intelligence and cognition as intertwined with sociality is also congruent with the recently fast developing movement of distributed and extended cognition (Hutchins, 1995; Clark, 2008). This approach stimulates new research directions and methods in psychology but also is visible in new ways of creating artificial intelligent systems, based on multiple communicating agents (see e.g., Steels, 2007; Cangelosi, 2010).

In the light of the theory of natural language as a system of replicable constraints, and independently of the debate on the existence of the symbolic constraints in the brain, linguistic symbols have the power to control the dynamics of the individual brains. Since natural language arises in social interaction, these controlling processes proceed according to socially designed directions. It is through situated language, then, that the evolved forms of sociality modify individual cognition, by constraining its dynamics developmentally and on-line. From this perspective, one can gain a fresh, and perhaps more ecologically valid look at the so-called linguistic relativity question. In a sense, accepting this framework, a researcher in language becomes more Whorfian than Whorf himself: language not only designs categories for perceiving and understanding the world but goes much deeper, pervading the ways we engage with our conspecifics in coordinating action in this world (Zinken, 2008).

One of the greatest consequences of Pattee's approach is that it makes us realize that the dynamics to be controlled must already be there: both the individual processes of perception/action and inter-individual coordination must be in place before language can arise and shape them further. It seems that the predominantly linguistic and symbolic way in which we express theories often makes us ignore this fact, or take it for granted. Paradoxically, the very same device that led to seeing minds as computing machines, can perhaps help us in understanding the complexity of dynamics involved. Now, however — unlike in the Good Old-Fashioned Cognitive Science since the 1950s, which relied on the machines' ability to conduct formal, algorithmic processes — we will rely on the recent ability to simulate large-scale stochastic processes, which result from non-linear interactions of multiple elements, in order to reconstruct such dynamics.

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