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Reconciling symbolic and dynamic aspects of language:

Toward a dynamic psycholinguistics

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Abstract

The present paper examines natural language as a dynamical system. The oft-expressed view of language as "a static system of symbols" is here seen as an element of a larger system that embraces the mutuality of symbols and dynamics. Following along the lines of the theoretical biologist H.H. Pattee, the relation between symbolic and dynamic aspects of language is expressed within a more general framework that deals with the role of information in biological systems. In this framework, symbols are seen as information-bearing entities that emerge under pressures of communicative needs and that serve as concrete constraints on development and communication. In an attempt to identify relevant dynamic aspects of such a system, one has to take into account events that happen on different time scales: evolutionary language change (i.e., a diachronic aspect), processes of communication (language use) and language acquisition. Acknowledging the role of dynamic processes in shaping and sustaining the structures of natural language calls for a change in methodology. In particular, a purely synchronic analysis of a system of symbols as "meaning-containing entities" is not sufficient to obtain answers to certain recurring problems in linguistics and the philosophy of language. A more encompassing research framework may be the one designed specifically for studying informationally based coupled dynamical systems (coordination dynamics) in which processes of self-organization take place over different time scales.

Keywords

Symbol; Information; Semantics; Psycholinguistics; Dynamical systems

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> Language disguises thought. So much so, that from outward form of the clothing it is impossible to infer the form of the thought beneath it, because the outward form of the clothing is not designed to reveal the form of the body.
>
> L. Wittgenstein, Tractatus Logico-Philosophicus (Wittgenstein, 1922)

1. Introduction

Most people would probably agree that language consists of a system of symbols even though considerable debate might arise as to what a symbol actually is. Recently, however, it seems that an increasing number of theorists are no longer content with the definition of language as a symbol system: Explanations of linguistic structures should also include dynamical aspects involved in language use, such as processes that occur in the communication, acquisition, and

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evolution of language (e.g., Smith, Brighton, & Kirby, 2003; Tomasello, 1999). For such dynamical aspects of language to receive serious consideration, it would seem necessary to specify how many kinds of dynamical processes are relevant, what is their nature, and how they relate to the symbolic side of language. The latter question, in particular, of understanding how dynamic aspects of language relate to symbolic ones, of how the continuous relates to the discrete, of how the static relates to the time-dependent, is an especially vexing, ever recurrent problem in a number of scientific fields. To investigate the symbol—dynamics relation, we have turned to theories that have considered the problem from the perspective of similar dualities in biological systems, specifically to the theories of the physical biologist Howard Pattee. Even though such an approach cannot, of course, solve all the problems pertaining to understanding language, we believe it may alter the way we look at language and perhaps shed new light on some persistent problems encountered while investigating it. At a bare minimum, for a framework designed to deal with information in biological systems to be useful also for investigating natural language, it should (1) help identify the relevant kinds of dynamics in language, and (2) justify the relevance to the study of language of tools commonly employed to investigate complex dynamical physical and biological systems.

2. Relation between symbolic and dynamic description in biological systems

Howard Pattee's work is concerned with explaining the interrelation between symbolic and dynamic descriptions of complex systems, most especially in living organisms. In his writings Pattee (1973,1977,1987,1989,1992,1997), claims that such duality of description is necessary when we consider two phenomena, characteristics of living organisms: control and measurement.

2.1. Control in living organisms

According to Pattee, control theory is designed to describe how to produce a desirable or predetermined behavior in a physical system by imposing additional forces or constraints. It is quite easy to imagine what "control" means in an engineering context. What seems to be difficult is to explain the origin of controls that arise naturally and how they are realized in a living organism, both on the level of molecular control of the formation of structures and on the level of the control of functional behavior (Pattee, 1987,2001, see also Cariani, 2001). The concept of control includes more than a fixed constraint or structure that permanently limits the motions of the system. Rather, control means limiting some degrees of freedom, leaving others unconstrained, thereby resulting in coordinated, yet flexible, action.

To picture arising of coordinated action in a somewhat simplified fashion, look at your hand, wave it, wave your fingers: it is a system with many degrees of freedom, constrained by the physical structure of your bones, joints, and muscles (this constraining is probably also "carefully" shaped by evolution, which happens on a different time scale). When unconstrained, it can move freely in many directions limited only by its physical structure. However, when an action is performed, such as grasping a mug, some movements of some parts of this multielement system have to act together in a spatially and temporally organized fashion. It is important to realize that the limitations imposed on the hand's degrees of freedom are not specified once and forever. One does not just switch on some automatic function called "grasp a mug". The action, and therefore the binding together of the degrees of freedom, has to be adapted, on-line, to the actual demands of the environment, such as the actual dimensions and shape of the mug, temperature of the liquid inside, etc. Still another important fact is that the specification of action to fit different situations has to be incomplete: one can grab a mug, even a specific mug at a specific distance, in many different ways: e.g., with a palm turned outside, with a hand holding a pen, etc. Therefore, flexibility of action depends on leaving some degrees of freedom unbound.

Constraining the behavior of a system in a functional way, i.e., control, can be exerted here and now—by the specific parameters of environments. Such is the case of tropisms: a plant turns in the direction of a light. However, in cases in which control is displaced in time, the functional "freezing" of some degrees of freedom has to be written somehow and somewhere (i.e., some form of memory must occur), and—if one wants to have a physical description of this memory process—according to Pattee, one has to employ an alternative sort of description in the form of time-independent constraints. This description is "symbolic" in the sense of consisting of timeless structures, having external significance, that—themselves—form a system, being non-arbitrarily linked together by certain rules. According to Pattee, the two kinds of description (symbolic code and physical laws) are incommensurate. Neither is reducible to the other.

An example investigated by Pattee is that of a living cell, in which the symbolic description is DNA. DNA regulates the development of a cell by selectively controlling the rates of reactions involved in protein synthesis. Chemical and physical laws may describe how this synthesis proceeds, but which proteins will actually be synthesized depends on the 'code': the rate-independent information contained in the genetic sequence. The meaning of such a code is closely tied to its role played within the system. In Pattee's words (1987, p. 337):

> (…) there is virtually no meaning to symbols outside the context of a complex dynamical organization around which the symbolic constraints have evolved.

and:

> (…) it is useless to search for meaning in symbols without complementary knowledge of the dynamics being constrained by the symbols (…)

2.2. Measurement in living organisms

Another process in which symbolic and dynamic descriptions appear together is in Pattee's theory of measurement. Measurement in biological organisms is defined much more broadly than measurement in physics (Pattee, 1989,1992,1997). The variety and complexity of patterns that can be measured is greater in the former than in the latter, and the outcome does not necessarily have to be symbolic. In most cases, however, a measurement is a symbolic result of a dynamical process. A selection of information occurs such that out of the number of dynamical processes that go on in the environment, only some give a result, and this result is limited to a particular moment in time. According to Pattee, the only way symbols could have originated is during processes epistemologically equivalent to measurement. A similar argument has been made in physics, for example J. Archibald Wheeler's "it from bit" (Wheeler, 1990).

Since organisms are not disinterested observers in the environment but rather an active part of it, the information they extract is specified by the demands of survival and control over the environment. This is how the two processes that necessitate symbolic description connect in Pattee's theory: the biological function of measurement is to control. Living organisms are able to form many kinds of such measurement—control networks. The outcome of the measurement process may feed directly into the control network (as in tropisms). But, according to Pattee, for control to be displaced in space and time (e.g., delayed with respect to measurement), a symbolic coding must exist. The two processes of measurement and control fulfill the difficult "cementing" role between the symbolic and the dynamic, the discrete and the continuous, the static and the time-dependent. Even though the measurement process may be a dynamical one, its function, according to Pattee, cannot usefully be described by the same dynamics it is measuring. It is only in this sense that dynamics and symbols (the informational record of a measurement) are "irreconcilable" or complementary (for more on complementarity and its origins in the coordination dynamics of the human brain, see Kelso & Engstrom, 2006).

3. Symbols of language as a "symbolic mode" of a dynamical system

It should be noted that symbols in Pattee's writings are quite different from symbols understood as elements of a formal system (which is how they are seen in most linguistic theories). Pattee's symbols are "grounded" (in the sense of Harnad, 1990): they are inseparably connected to dynamics; they do not need any external intelligence to couple them to their meanings. Meaning stems from the role symbols play in controlling and measuring dynamical variables. The thought experiment presented below consists of trying to imagine symbols of natural language as a symbolic mode of a larger dynamical system and to think of them as grounded in a similar way.

Adopting Pattee's picture of symbols and their role, the main task will be to specify the dynamical processes constrained and "measured" by the symbols of language. The possibility of using such a framework (in fact, the very possibility of asking questions about dynamical processes in natural language) rests on two main considerations that tend to run contrary to many approaches to language (especially within the field of linguistics, including those based on the structuralist paradigm): (1) a shift in explanatory priority that assigns symbols to effective rather than to representative functions; (2) including in the theory of language not only synchronic but also diachronic aspects. This means, contrary to claims such as de Saussure (1959) in which:

> Diachronic facts are (…) particular; a shift in a system is brought about by events which not only are outside the system, but are isolated and form no system among themselves. (p. 95)

That shifts in a system are brought about by events that do, in fact, belong to the system, and —more importantly—that changes within the system may themselves be informative as to the nature of the forces that sustain language structure.

The foregoing considerations are hardly new. Consider Ludwig Wittgenstein's later works (1953) in which he treated symbols as instruments in the interaction (i.e., as "doing something") rather than as mere representations (i.e., "standing for something"). One may recall also Merleau-Ponty (1960/1999) criticisms of de Saussure:

> Synchrony is just a slice through diachrony, and thus a system which is actualized in synchrony is never fully realized, it always contains latent changes or seeds of change (…). p. 161/162

Including dynamical processes in a more complete picture of language is a difficult task not only because of the symbolic/dynamic complementarity but also because of the variety of dynamical processes. Identifying the dynamic mode of description requires taking into account functions of language, which are realized through processes happening over different time scales: communication, language learning, and language evolution. A detailed characterization of each of these interdependent processes would exceed the scope of this paper. Here we illustrate the symbolic/dynamic interrelation in a couple of cases concerning both the constraining role of symbols as well as the emergence of symbols as an outcome of dynamical processes. We also hint at the relationships of dynamics operating on different time scales.

3.1. Symbols of natural language as constraints

In natural language, symbols can be understood as constraints imposed on several kinds of dynamics. The two most obvious are dynamics of interpersonal communication and dynamics of conceptual development. Here we focus on the former, bearing in mind that developmental dynamics are no less important than, and closely intertwined with the dynamics of communicative events. In some traditional frameworks, communication is often described as an exchange of symbols between participants. Symbols have some meaning "encoded" by a speaker and “picked up” by a listener. This “container” metaphor of a symbol (as Lakoff & Johnson (1980) labeled it) seems to be prevalent in many theories as well as in common knowledge about symbols. Some problems with such a view stem from assuming that (a) every time a symbol is used the meaning conveyed is the same (except in the cases of polysemy), and (b) a symbol is an independent and potent entity, whose “content” suffices to evoke a particular meaning in a listener.

If, however, following Pattee, and in line with more pragmatically oriented frameworks, a symbol is considered to be just an element of a situation of communication, an element which has a function of affecting a listener in a certain way, it becomes clear that symbols almost always underdetermine what is really being conveyed. The rest is supplied by context: linguistic, situational, as well as variables characteristic of both the speaker and the listener. Without such a context, symbols have no meaning. A symbol “uses” all the other factors present in a situation; it can “rely” on the natural dynamics of communication. Therefore, what a symbol “does” is always relevant to a particular moment. This underdeterminacy of meaning conveyed by a symbol—which used to be a problem in some theories—is, in fact, the power of language, because it is the source of its *efficiency* (Barwise and Perry, 1983). The same sentence means something different when spoken here and now than when spoken there and then. Linguists often emphasize the productive side of language—that it is possible to generate an infinite number of sentences. But it is no less amazing that the very same sentence uttered in different situations may have a completely different meaning.

Accepting such a view of symbols may explain why it is difficult or, in some cases, impossible to find a set of features characterizing a symbol’s reference (take, for instance, Wittgenstein’s famous example of the word *spiel* [game]). It seems that such a difficulty stems from trying to infer the meaning of symbols from a number of possible understandings that are actually the “end-products” of a symbol’s “action”. The problem is that these end-products may have nothing in common across situations. It does not mean, however, that a symbol does not contribute something invariant, but that other factors—situational and contextual—which strongly contribute to these end-products, may conceal this invariance. Thus, understanding a symbol should be seen as a dynamical process, in which a symbol itself plays the role of a constraint.

3.2. Symbols of natural language as “outcomes of measurement”

The constraining function of symbols is only one part of the story. To make the picture of natural language more complete, it should be clear where the constraining properties of symbols come from, or—on a more general level—how symbols arise. Let us fall once again in step with Pattee’s theory and treat symbols as outcomes of a process formally equivalent to measurement. Symbols “encode” dynamical variables that are important from a control point of view. In the case of symbols of language, those variables pertain to coordination between individuals in a given environment. Some of those include perceptual variables, intentions toward perceived objects or situations, etc. It seems that in order to be “measurable”, such a pattern of variables has to have some temporal stability with respect to a perceiving organism. In a given situation there can be many such stable patterns; choosing one and ascribing a symbol to it may stabilize it further. Perhaps the existence of such stability is a necessary condition for a symbol to emerge and to be meaningful. How do symbols gain their informational nature? Here, perhaps, Pattee’s framework might be amended or extended by Kelso’s view (Kelso, 1994,2002;Kelso, 1995) of information arising as a result of the system’s metastable coordination dynamics. There, information is created (or annihilated) because of symmetry breaking in a multistable system that contains many different kinds of component elements.

Once a pattern of dynamical variables changes in a way important for an organism, symbols also have to change. However, once a symbol is created, it remains relatively static, playing the role of a constraint on processes that act on faster time scales. As a consequence of communicative and learning experiences, symbols stabilize further the pattern of variables originally measured, becoming a form of nonhereditary memory. Symbols thus arise in a process of selecting stabilities in the relation between the environment and an individual's efforts to coordinate in that environment. They are ascribed to informationally important ranges of values of dynamic variables. Perhaps the mechanism is, as Cariani (2001) imagines it:

> In the case of neural signaling systems as well as in the cell, there are also means of reconciling dynamical models with symbolic ones—attractor basins formed by the dynamics of the interactions of neural signals become the state symbol-alternatives of the higher-level symbol-processing description

It is important to note that understanding what a symbol has "measured" requires looking at a different time scale than the one pertaining to the constraining role of symbols, namely, the one on which symbols themselves change. On the short time scale of scientific observation and language use, only the end product of language evolution is accessible: a system of symbols linked by the rules of grammar. Instead, therefore, of searching for "essences" of symbols at this time scale one might rather ask: Which variables were important enough in the relation between the environment of an individual or in the relations between individuals such that they were encompassed by symbols? The problem that arises in such a view is similar to the one encountered in theories of biological evolution: the variables "measured" may not be directly seen from the present functions of symbols in communication and learning.

After the creation of symbols in a process equivalent to measurement, a ruthless "natural selection" occurs based on, among other factors, how well symbols fulfill their controlling functions. Of course, as in the evolutionary history of anatomical structures (Gould, 1991), the evolutionary history of linguistic symbols and structures also may not be straightforward: they may be "borrowed" to perform a different function or may appear as byproducts of other adaptations. Perhaps in the evolution of language, "exaptations" and "spandrels" occur just as frequently as in biological evolution itself.

To summarize, after Pattee we have distinguished two processes that necessitate symbolic description: measurement and control. In one of those processes a function of a symbol is to "bind" relevant variables, in the other it is to exert a specific influence over dynamical processes of communication and learning. Which of those functions should be considered "the meaning" of a symbol? It seems that, if one adopts a picture of language that contains both symbolic and dynamic aspects, it becomes necessary to embrace also a richer picture of linguistic meaning, one that would encompass all the aspects mentioned above. This, in turn, requires an account of the interrelation of meaning components and the interaction of the time scales characteristic of them.

At least three different, but interrelated time scales can be identified on which dynamic events relevant to constitution and functioning of symbols take place. On the slow time scale of language evolution, symbols preserve certain specific measurements of dynamical variables. However, shorter time scales are also relevant because the communicative needs of individuals, realized on these time scales, determine which symbols are selected, in a process akin to "natural selection". Only those symbols that constrain the communication situation in a desired and effective way "survive". Between the slow time scale of language evolution and faster processes of communication, there are events that happen on the time scale of ontogeny, which also create pressures on the selection of symbols and symbolic structures. It seems that one criterion in the selection process, besides the effectiveness of the controlling function of a symbol in a communicative situation, is how easy it is for a child to learn to use a given symbol. One of the sources of linguistic structuring might also lie in learning considerations, as shown by Smith et al. (2003).

3.3. Grammatical rules

So far we have considered symbols as separate, independent entities. The symbolic mode of language, however, is a system, and relations between symbols are no less important and no less meaningful than symbols themselves (e.g., Wierzbicka, 1988). For most theories, grammar is the necessary and sufficient property for something to be described as a language. Indeed, some consider a description of grammatical rules the most important task of the linguist. A subset of those rules, which are specifically linguistic, is claimed to be represented in the human mind in the form of Universal Grammar, and used in the processes of language production and understanding (Chomsky, 1988; Pinker, 1994).

However, the fact that expressions of language can, in principle, be described by a system of rules does not necessarily mean that those rules exist in any other place but the observer's eye or mind. It is one thing to obey a rule, which is somehow represented within a system, and still another to act as if the rule were present—i.e., to behave according to a rule without even knowing it (see, e.g., Wittgenstein, 1953). Thus, a driver approaching a crossroads may stop because her visibility is restricted and she wants to be sure that there is no one coming at her. To the observer, this behavior might look as if she were obeying a stop sign placed there. However, one can see that attributing the behavior to obeying a rule allegedly represented by the driver ("stop if you see a STOP sign"), fails to point uniquely to the real cause and real function of stopping, mistaking it for obeying a rule rather than assuring safety and survival. Paraphrasing Gibson (1966), behavior may be regular without being regulated by rules sitting inside the agent.

According to other linguistic theories, rules governing co-occurrence of symbols are descriptions of regularities found in more general cognitive abilities to structure the world and stem directly from semantic properties of symbols (Lakoff & Johnson 1999; Langacker, 1982). These and similar conceptions (e.g., for the case of second language learning see also Ellis, 2003, 2007) are more congruent with a view of language as a dynamical system. As in other systems that make measurements, the configuration of symbols stems from the interrelation of variables they measure, the interrelation of the constraints they impose, and the structure of a measuring device. The communication process may concern variables whose level of complexity is too great to express with single symbols. Several recent theories explain the necessity of the emergence of grammar by semantic complexity of the content conveyed by symbols and communicative economy (Batali, 1998; Schönemann, 1999). Rules describing regularities in language may indeed capture the interdependencies existing in language, but it is possible that in some cases they capture only a surface similarity of symbol structures that may be the effect of quite different measuring/control properties. Thus, formal properties of individual words or expressions that are inferred from their co-occurrence may not be enough to capture the principles of grammar. In some cases, in the information measured by one symbol there may be an inherent element of information measured by another symbol. Or it may occur that in the information evoked in the listener's mind by one symbol there is inherent information of other symbols that will likely follow (as in the case of the names of activities requiring that a direct object follows). This does not mean that the regularities found in the data are useless, only that how one interprets them may be different. Instead of being an explanation for anything, they are rather surface indications of deeper, semantic dependencies stemming from symbols' functions.

The search for semantic and pragmatic sources of compositionality and productivity of natural language can be seen for example in Harnad (1990). Harnad accepts that iconic and categorical representations, in which symbols are grounded, influence in a non-arbitrary way how symbols can be combined. Theories going even further in this direction include Lakoff and Johnson's (1999) view of embodied representations and Glenberg's (1997) theory in which embodiment of symbols has a form of defining meaning as a pattern of possible actions.

4. Consequences for research on natural language

A view of language that encompasses both symbolic and dynamic aspects demands that the study of language should include a description of linguistic structures as well as cognitive and social processes that give rise to those structures and that are constrained by them. Such a research program, however, requires taking into account a vast amount of information. All the causes and effects of an utterance are situationally, historically, and contextually dependent. Variables that are 'measured' by a symbol are difficult to specify. The picture gets even more complex when we realize that the slow processes that shaped our language are not readily available on the time scale of an experiment or observation. All we have at a given time is a complicated system of symbols that arose through thousands of years of language evolution, and that are used to constrain complex, ever changing, and interpersonal situations. It seems that the outcome of specialization of disciplines concerned with language (linguistics, psycholinguistics, sociolinguistics, discourse analysis, etc.) was a division of labor, a delineation of sensible fragments, or aspects, of natural language that renders them amenable to study. Putting them all back together may seem a step backward, introducing a complexity that is hard to disentangle; a mess, out of which it is impossible to make any sense.

One possible way to deal with such a complexity and with dynamics on different time scales is computer simulation. Recently this tool has been spectacularly successful in showing possible mechanisms underlying structuralization of language, emergence of coordinated systems of representations, and possible symbol grounding scenarios (Batali, 1998; Schönemann, 1999; Smith et al., 2003; Steels & Belpaeme, 2005). A good exposition of the main aims and hopes motivated by such methods can be found in Cangelosi and Parisi (2002). However, this method can only proceed in parallel with linguistic investigations of natural languages and psycholinguistic experimental studies on human language processing. The latter may help establish the psychological reality of concepts as well as yield parameters for simulation studies.

Although the apparent complexity and diversity of symbols' function in a dynamic system of linguistic interactions seems overwhelming, a branch of cognitive and behavioral sciences designed especially for studying complex dynamical systems in nature might be of some assistance. Introduced in physics three decades ago (Haken, 1977; Nicolis & Prigogine, 1977; Prigogine & Stengers, 1984/1990), the theory of complex dynamical systems (mainly dealing with pattern formation in open, nonequilibrium systems) was found to have much broader application. Beginning with studies of motor control and coordination (Kelso, Holt, Turvey, & Kugler, 1980; Kugler, Kelso, & Turvey, 1980, for an example in speech production see Kelso, Tuller, Bateson, & Fowler, 1984) the approach was extended also into domains usually regarded as more 'cognitive', such as perception, perception—action coupling, pattern recognition, learning, motor and cognitive development, and even interpersonal coordination (see, e.g., Haken, 1990, 1996; Kelso, 1995; Kelso, DelColle, & Schöner, 1990; Schöner, Zanone, & Kelso, 1992; Nowak & Vallacher, 1998; Turvey, 1990; see also Tognoli, Lagarde, DeGuzman, & Kelso, 2007 for a more recent example of work on social coordination dynamics in the field of social neuroscience). Moreover, a theoretical basis for understanding pattern generation in the nervous system was also elaborated (Kelso, 1991; Schöner & Kelso, 1988).

In short (for a more detailed description and review see Kelso, 1995), this approach aims to identify the dynamics underlying changes of various, relatively stable perceptual, cognitive, and behavioral patterns. The usual route to this goal involves: identifying the relevant (functional) pattern variables (the so-called order parameters, or collective variables that characterize the ordering in space and time among multiple interacting elements or processes); finding the parameters that lead or guide the system's change of these patterns (the so-called control parameters); mapping observed patterns and pattern change onto attractors of the order parameter dynamics (a first step in modeling); and studying the pattern dynamics (adaptability, multistability, flexibility, coexistence of multiple states, metastability, hysteresis, etc.). The outcome of this method is a low-dimensional dynamical model specified in terms of collective variables, that captures the essence of the system's complex behavior. Importantly, such theoretical modeling has afforded a systematic test of predictions concerning the stabilization and change of behavior on multiple levels of description (see Haken, 1996; Kelso, 1995 for reviews).

Treating language as a dynamical system, of which the traditionally studied "system of symbols" is a symbolic mode, seems to justify application of these methodological tools also for studying linguistic phenomena. This becomes a study of dynamical pattern-forming processes underlying the emergence of symbols as well as those involved in functions that are essentially constrained by symbols such as language understanding and cognitive development. The assumptions upon which such an approach to language is based are that behavior consisting of symbol production involves temporal stability in a cognitive system and that symbol use influences concept formation and stabilization (e.g., in a listener during the process of understanding). The main practical postulate of research conducted within a dynamical systems framework is that one can learn most about a given system by observing it in situations in which it undergoes sudden change, i.e., in situations in which stable patterns lose stability and new patterns emerge. A change of symbols would then, in principle, be treated as a consequence of a change in an underlying dynamics: since symbols "live" on several time scales, the relevant dynamical events also should be sought at various time scales.

4.1. Change of symbols as a consequence of underlying dynamics

One such time scale, as we already mentioned, is the long time scale of language evolution, in which symbol change may be considered the manifestation of a change in the configuration of dynamical variables that are significant to an organism. In the dynamical framework, as elaborated by Kelso (1990,2003) for cognitive processes, only some (discrete) regions of the order parameter/collective variable dynamics are informationally relevant. The sudden nonlinear change in the value of an order parameter brought about by the continuous change of control parameters is one of the main characteristic of nonlinear dynamical systems. This is perhaps a convenient way of dealing with the continuous/discrete duality. Symbols are discrete because they are treated as measurements of pattern variables that are temporarily stable but that may undergo abrupt and rapid change.

In psycholinguistics there are already attempts at uncovering relevant dynamical patterns that may correspond to symbols. For example, Wildgen (1990) treats semantic distinctions as stemming from the organization of the perceptual field and shows how perceptual "states" (dependent on continuous parameters) may map onto discrete semantic distinctions. Using examples of color names and evaluative adjectives, Wildgen shows that mapping of a perceptual situation onto symbols may change or not depending on the trajectory that the system has taken through the state space. In another study, this time on the semantic classification of verbs, Wildgen used information proposed as significant by the coordinative structure theory of movement (Kelso et al., 1980; Kugler et al., 1980), again trying to identify basic dimensions underlying symbol change.

On the level of grammatical structures a similar research strategy has been used to uncover the semantics behind relations between symbols. Dynamical understanding of language structures has been presented by Petitot (1995) in his morphodynamical approach. Grammatical relations are modeled dynamically as relationships between attractors, expressing dependencies present in perceptual scenes (Petitot, 1995). Some studies in the semantics of grammatical relations, although coming from a quite different school of thought, seem to show a tendency in the same direction. For example, Gropen, Pinker, Hollander, and Goldberg (1991) attempted to uncover variables in an event that underlie ascribing the role of a direct object to a physical object. They found that the most crucial variable was something called "affectedness"—i.e., being changed or affected in a given event. The Gropen et al. study did not use methods of dynamical analysis, and thus had nothing to say about how context affects decisions. However, we view it as a step in the direction of uncovering potentially important perceptual/conceptual bases of grammatical structures. One should note here that the uncovered variable could not easily have been presented in terms of a simple (perceptual or conceptual) semantic feature. In general, variables "measured" by symbols may be complex and quite abstract rather than simple and concrete.

4.2. Dynamics constrained by symbols: examples from two time scales

Symbols act as constraints in at least two, interconnected, processes: on-line understanding and conceptual development. Understanding language is a dynamical process in which a temporally stable perception of meaning emerges under the influence of many constraints: symbolic, situational, and emotional. Although we are unable to take into account all of the factors that influence language understanding, we may observe crucial influences such as context or the intrinsic nature of the symbols themselves. The effect of the latter has been investigated in studies using words (Tuller, Case, Kelso, & Ding, 1994) or ambiguous sentences (Rączaszek, Shapiro, Tuller, Case, & Kelso, 1999; see also Kelso et al., 1994). In the Rączaszek et al. study, subjects were presented with phonological or prosodic cues congruent either with one meaning of a sentence ("[Pat or Kate] and Bob will come"), with the alternative meaning ("Pat or [Kate and Bob] will come"), and with the intermediate steps between the two interpretations. We found that the initial interpretation of symbols remained unchanged in the face of changing symbolic information. We also showed that switching to an alternative understanding of symbols depended on previous experience with the stimuli, i.e., the same symbols evoked different understanding depending on which interpretation had already been formed. Such results suggest that the formation of real-time language understanding is a dynamical process, with alternative understandings corresponding to stable states.

In another study, using a cross modal lexical decision paradigm, Raczaszek-Leonardi, Shapiro, Tuller, and Kelso (2007) studied the on-line adaptation of category names in context. Reaction times and variability data suggested that such adaptation to context takes place in a 300–450 ms window after hearing a word and may take the form of rapid conceptual reorganization rather than the mere linear activation of specific category members. Although the data are still preliminary, this study shows that measures suggested by the dynamical approach may be useful in the investigation of on-line language processing.

Previous attempts at treating symbols as functional constraints may be seen in the work of Verbrugge (1985). According to Verbrugge, symbols are just a part of a situation of communication. Their function is to attune a participant in a communicative event to various aspects of a situation, and prepare him/her for certain perceptions and actions. Other theorists and researchers have emphasized similar functions of "language as a systematic support for social perception and action", as Verbrugge puts it, both at the time scale of development and communication. For example, Tomasello (1999) has pointed to the role of language in cementing shared attention episodes and in guiding the attention of others in a social environment. This, in turn, helps achieve specific interpersonal goals.

The constraining properties of symbols are no less important when it comes to influencing the dynamics of cognitive and social development. There, symbols may be seen to play a stabilizing role in the process of concept formation. Besides effecting temporary changes through attunement to specific aspects of a situation, symbols may also influence more permanent attunements, or general ways of perceiving and interpreting social situations (a kind of linguistic bootstrapping). Numerous studies have demonstrated cultural differences in cognitive development that correlate with differences in linguistic structures. For example, Gopnik, Choi, and Baumberger (1996) showed that English and Korean children differ in their conceptual development, probably because of different early linguistic experience. Language development from such a perspective could be seen as a culturally specific constraint structuring perception and understanding of social situations.

5. Summary

Two major points were put forward in the present article. The first concerned the very nature of symbols in language. We drew attention to the difficulty (if not the impossibility) of finding a context-independent reference for symbols. We suggested two reasons that may require abandoning the definition of symbols as static forms that are manipulated independently of their content: (1) the flexibility of symbols in context as well as over the course of evolution, and (2) the stipulation that a symbol's primary function be effective rather than representative. It may be more convenient to view symbols as corresponding to temporally stable patterns, having a function of measurement, and as acting as constraints on shorter time scale processes such as understanding and conceptual development. The main consequence of such a dynamic view for the theory of meaning is that instead of trying to formalize meaning in yet another symbol system, one should look for dynamical processes underlying the formation of symbolic forms, and in turn, how dynamical processes are constrained by symbol use.

The second point that stems from embracing such an approach is that language may not be explainable at the level of an individual and his/her knowledge. In the present perspective, language arises as an interindividual communication "tool" and thus its structures are shaped not only by the cognitive properties of individuals but also by cooperative phenomena beyond the individual level. A symbol's "measurement" function, although perceptually grounded, stems from its use at the level of communicative events. The pressures for interpersonal control on the one hand and individual perceptual capabilities on the other are two of the forces that shape language as a self-organizing system.

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