Multiple Systems and Multiple Time Scales of Language Dynamics: Coping with Complexity

Joanna Rączaszek-Leonardi

This paper follows consequences of applying a view on symbols, which presents them as replicable constraints on dynamics. On the background of a brief history of symbol- versus dynamics-oriented explanations in cognitive sciences this view is presented as a possible third way, able to link these two aspects of cognition. The consequences for the study of natural language are presented: In this area such a view allows for critical evaluation of common assumptions about language and opens promising ways for its study. However, it is pointed out that language from this perspective becomes a mind-bogglingly complex phenomenon, involving a multitude of embedded and co-depended time scales and systems. Attempt at identifying some of them is made and the paper concludes with an assessment of computer simulation as a theory-building tool in such complex cases. It is noted that both the complexity and non-linearity of dynamical processes involved and the irreversibility of natural selection of constraints limit in a particular way the predictability and possibility of generalization of such a theory.

Keywords: Language, dynamical systems, symbols, dynamics, time scales

Introduction: The Complexity of Language

A viable theory of language cannot possibly be simple. Already when understood as a product of a generative device in an individual’s head, language shows stubborn unruliness, which is evident in the multiple efforts at constant modification of grammatical theories to “deal with the ‘spills.’” The complexity increases with the view—now more commonly accepted—that language’s main function is inter-individual coordination (and not manipulation of intra-individual representations) and that therefore explaining language involves studying processes of interaction (e.g., Schegloff, 1996) and not only individual minds.

Recently however, we see other changes in defining language as the phenomenon under study, which also crucially bear on its complexity. In response to (among others) the ever-present symbol-grounding problem in cognitive science and psycholinguistics (for details see next sections), we witness the rise of the significance of the acting body in the theory of cognition (which becomes a theory of cognition-controlled behavior). Just as other cognitive skills, language is thus claimed to be embodied, situated and distributed, and thus linguistic structures, instead of being independent ‘vessels for meaning’, are seen as immersed in a variety of dynamical events that give rise to them and are, in turn, controlled by them.

1. Faculty of Psychology, University of Warsaw, Warsaw, Ul. Stawki 5/7, 00-183, Poland
   Email: raczasze@psych.uw.edu.pl
This means that language cannot be detached from action and co-action in environment to become conveniently isolated for structural analyses. This is because important explanatory concepts regarding the nature of language lie in the individual and collective dynamics, outside the level of linguistic structures themselves and outside individual mind. On such view, communication, instead of being meaning transfer between individuals is rather seen as creating something-in-common, or communion, that is, formation of temporal, adaptive wholes, in which individuals coordinate in functional synergies (Fusaroli, Rączaszek-Leonardi, & Tylén, 2014).

Now the complexity becomes truly mind-boggling: There are multiple ways in which language aids formation of functional synergies, engaging multiple levels of coordination within different systems and time scales. Thus one of more urgent tasks of a theorist of language, instead of, for example, designing elegant generative machines, becomes to explain how language controls collectivity (Rączaszek-Leonardi & Cowley, 2012). This, in turn, involves a nontrivial job of explaining how structures of language link to dynamical processes within multiple systems and over multiple time scales. The way individuals coordinate here and now via language crucially depends both on the way they were prepared for this in biological, cultural and developmental time scales and on how language was “designed” for this, in self-organizing processes over multiple time scales.

One has to start somewhere though. One possible point of departure is identifying the relevant time scales of change, that is, identifying those dynamical processes that give rise to structures of language and those dynamical processes that are controlled by these structures. Bringing some order into this mass of interacting events by applying a specific theory of how symbolic structures link to dynamical events is the first goal of this paper: On the background of the history of thinking about cognition and language in cognitive sciences, I will present a particular theory, which enables relating something as symbolic as an expression of language to anything as dynamic as human coordination. Next, I proceed to consequences of this theory for the view of language and to identification of time scales and systems of its relevant dynamics.

The second goal of the paper is to ponder the role of a computer simulation as a form of theory that is suitable for dealing with such complexity. The picture of language at which we shall arrive in the consequence of applying the view presented in the first part of the paper, shows that the symbolic structures of language are dependent both on lawful, self-organizing dynamical processes and on the—irreducible to these processes—selected historical paths that are responsible for finding a particular structure at a particular (improbable from the purely physical point of view) time and place. Thus computer simulations, even though increasingly able to account for physical dynamical events, due to this dependence on particular historical path, will always suffer from (or be blessed with) inherent limitations of generalizability of particular cases to types of events (Rączaszek-Leonardi, 2014). The latter will make it clearer why, and in which aspect, the theory of language will always have to remain outside of reach of physicalist explanation and inside the realm of a historical, humanist one.
Theoretical Framework for Linking Symbols with Dynamics

Analysis of the history of cognitive sciences makes evident a theoretical divide, roughly preserving the Cartesian separation, in posing in the center of explanation either the rules of a symbolic mind or the dynamics of a body acting within an environment. The same divide pertained also to theories of language, in this domain with a heavier accent on the first approach. Below I briefly present the key differences between these approaches in general theories of cognition and in theories of natural language and introduce an approach that seems to be able to bridge this divide.

Cognition: Algorithmic or Dynamic?

In the framework of good old-fashioned cognitive science, cognition has been conceptualized as symbolic computation, performed on representations residing in an individual mind/brain (e.g., Newell & Simon, 1976). The theory of cognitive function most often placed its explanatory constructs solely within the realm of these representations, detaching it from the bodily realization of the proposed symbolic processing. The enthusiasm for the form of cognitive theory as a computer program (Simon, 1957, after Dreyfus, 1972, p. 76) must have been intense: A newly found freedom from behaviorism that allowed explanation via internal processes, together with the development and popularity of “intelligent machines” led to concentration on res cogitans and on cognitive skills requiring such (specific) kind of algorithmizable intelligence.

But from the very beginning of this innovative program in the exploration of cognition it was obvious, at least to some, that behind the successes in modeling such intelligent behavior as proving mathematical theorems and game-playing, there are assumptions, which are by no means obvious nor their justification was easily demonstrable. To name just a few key ones: Such was the assumption that the putative symbolic representations in an easy way map onto the objects and events in the external reality, that it led to the now famous grounding problem, present in various forms both in early (Dreyfus, 1972) and later critiques of the paradigm (Dreyfus, 1992; Searle, 1980; Harnad, 1990). No less mysterious was the assumption that brains somehow realize symbols. After all, symbols seemed to be clear-cut discrete entities and it is by no means obvious how the dynamical flow of neural activation corresponds to them or operates on them. The fact that various architectures of computers are able operate on symbols does not alleviate this problem: Computers were specifically designed to curb their natural dynamics into clearly specified, categorical regions in their physical state-space, which is a feature that brains probably do not posses.

A much less prominent approach to cognition that developed in parallel to the information-processing framework seemed to be free of these pitfalls. Established as a separate school by James and Eleanor Gibson, ecological psychology was rooted, through James Gibson’s teacher, Edwin B. Holt, in William James’s radical empiricism (Heft, 2001). Not denying the importance of cognitive system for
meaningfully connecting external situations with organisms’ activity, ecological psychology rejected the idea that this connection happens via symbolic representations in the mind that map onto external objects and events. The focus of the approach was the inseparable organism-environment system and the main tasks were to understand the processes of picking up relevant, already complex information, which specifies the organism’s behavior and the preparation (tuning) of the cognitive system for directly picking up such relevant information from the environment. The tuning takes place in evolution (when senses become dedicated perceptual systems, Gibson, 1966) but also in development (Thelen & Smith, 1994) and through experience (e.g., Zanone & Kelso, 1997).

In a sense, the environment, in which living organisms evolved and act, in-forms the organismic structure in such a way that the environmental variables are directly meaningful in specifying the actions. “Ask not what is in your head but what your head’s inside of” (Mace, 1977, p. 43). Affordances, that is, action possibilities, are perceived directly and thus the symbolic representations are not necessary, or even, can be considered harmful for theorizing about cognition, substituting an apparently obvious symbol for a variety of dynamical processes that should be studied (Freeman & Skarda, 1990).

Devoid of symbolic representations, ecological psychology can be thus characterized by the focus on dynamic coupling between the organism and the changing environment. As fruitful as this approach has proven in movement sciences, it struggled with critiques concerning its applicability to the explanation of memory processes (see Freeman & Skarda, 1990; Freeman, 2001 for a contrasting position) and “higher cognition” (see Thelen & Smith, 1994; Reed, 1996; Smith & Thelen, 2003 for a contrasting position). For these problems in cognition, explanations involving symbol processing seemed more convenient.

Those who saw both the importance of dynamics and of the processing similar to symbolic computation in explaining adaptive behavior, proposed various means of integration of these views. Most often, however this integration took form of the dynamic and symbolic subsystems, or modules, working in parallel but responsible for different aspects of cognition (see, e.g., Neisser, 1976; Neisser, 1994; McClelland, 2009 for a critique of such a strategy in recent hybrid systems. For a more detailed account, see Rączaszek-Leonardi, 2014). Yet it seems that, even at the very beginnings of the modern cognitive sciences, there was a way of truly integrating the symbolic and dynamic approaches to cognition. It did not consist in reducing one approach to the other, nor in proposing differently-operating modules, but in proposing how symbols relate to dynamics and how the two kinds of description are complementary and indispensable for each other. Before I turn to this approach, let me show how the differential focus on symbols versus dynamics, present in information-processing and ecological psychology, manifested itself in research on natural language.
Language in Symbolic and Dynamical Cognitive Theories

Natural language seemed to be especially amenable to theorizing in terms of the processing of symbolic structures. For example, Chomsky’s program (Chomsky, 1957, 1965) situated the source of linguistic structure in the mind of an individual in the form of an algorithmically describable generative machine. This program was one of the pillars of the newly emerging cognitive science in the 50s and 60s and modern psycholinguistics owes most of its research paradigms and a substantial body of systematic knowledge on individual language processing to this school of thought.

In theories of natural language, the two key problems mentioned above (the grounding problem and the symbol realization problem) seemed less burning. The problem of grounding symbols was delegated to the semantic theory, thus syntacticians could focus on the formal description of language. The problem of their realization received a typical information-processing solution: Symbols were words, or linguistic expressions “stored” in a “mental lexicon.” Today the solutions to these problems seem less obvious: syntactic processing seemed increasingly in demand of semantic specification of elements, while at the same time this semantic specification occurred to be far from easy. Similarly the mental representation of linguistic building blocks in “mental lexicons” seemed to do just what Freeman and Skarda (1990) warned against: reifying—as mental representations—complex processes of word recognition and use without actually explaining them (see, e.g., Elman, 2004; Port, 2007).

On the other hand, the ecological perspective in the area of language research, similarly to other areas of cognition, focused mainly on the perception-action loop, resulting in much valuable research in the domain of speech (e.g., Fowler, 1980). Reed (1996) included language in his reformulation of the main problems of cognition from the ecological psychology point of view, however the conception on other aspects of language than speech at these times seemed rather far from the concreteness of the testable theories of the mainstream psycho-linguistics.

Symbols and Dynamics Together: Irreducible and Causally Connected

Let’s now introduce the approach, which from the 60s onward advocated a specific integration of symbolic and dynamical aspects of cognition. It is visible in many early works (e.g., Polanyi, 1968; von Neumann, 1966) on the theory of information in living systems, however, the account that most closely addressed the problems in contemporary cognitive science was that by Pattee (1969, 1972, 1982a). This account and its links to the theory of language and cognition were presented elsewhere (Rączaszek-Leonardi & Kelso, 2008; Pattee & Rączaszek-Leonardi, 2012). I will briefly summarize that perspective here and point to the differences in understanding of the key notions of the symbol and its meaning as distinct from traditional approaches, especially the information processing one.

The main claim of the approach is that neither of the accounts, symbolic nor dynamical, is sufficient for a theory of cognitive phenomena. As Polanyi noticed in his Life’s Irreducible Structure (Polanyi, 1968), dynamics, describable by laws of physics,
will not account for morphology of a device that performs a function (or morphology of functionally adapted organism). This is because morphology is an outcome of purposeful design in the case of machines and of natural selection in the case of organisms. Similarly, Pattee pointed out that even the detailed description of a functioning structure in terms of laws of physics will not account for the way in which the degrees of freedom of this structure are bound together to perform a coherent function. In order to bind the degrees of freedom, constraints are needed and these constraints and their role in a system cannot be described by the same laws. Pattee calls these constraints symbolic and their structure: a generalized language. A system, which demonstrates an increase in adaptive complexity thus requires complementary descriptions both in terms of dynamics and in terms of symbols. In a development of this view it was underscored, that physical structures serving as constraints have to be replicable, in order to carry the constraints through space and time and in order to be subjected to selection (on the basis of the adaptability of the outcomes of their constraining [Pattee & Rączaszek-Leonardi, 2012]). The most important feature of such understanding of symbols is that if symbols are just constraints on dynamics “there is virtually no meaning to symbols outside the context of a complex dynamical organization around which the symbolic constraints have evolved” (Pattee, 1987, p. 337)

Let us see how a symbol understood in the works of Pattee and others mentioned above differs from the notion of a symbol in traditional cognitive science (which is how a symbol is understood in formal systems). Table 1 below lists the differences and their main consequences.

**Table 1: Symbol: Redefinition**

<table>
<thead>
<tr>
<th>Symbol in a Formal System</th>
<th>Symbol as a Constraint</th>
</tr>
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<tbody>
<tr>
<td>Abstract formal structure</td>
<td>Physical structure</td>
</tr>
<tr>
<td>• Independent of dynamics (grounding problem)</td>
<td>• Structure which arose in the context of particular system-organism dynamics</td>
</tr>
<tr>
<td>• The causal role for dynamics (physical events) difficult to explain</td>
<td>• As a physical structure it can have a causal role with respect to dynamical events.</td>
</tr>
<tr>
<td>• Unclear how symbols get into a cognitive system</td>
<td>• The presence of a particular structure in a particular time and place is not accidental: It is an outcome of a history of a structure within the system (including natural selection).</td>
</tr>
<tr>
<td>• Independent level of explanation (<em>res cogitans</em>)</td>
<td>• Not an independent level of explanation (<em>res cogitans always with res extensa</em>).</td>
</tr>
<tr>
<td>• Symbols are manipulated according to syntactic rules, independently of their meaning (on the basis of their shape alone).</td>
<td>• Symbols do not “behave” according to rules but rather their structures depend on dynamics within which they arose and which they control.</td>
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Applied to language, this third way, (i.e., one that does not try to dissolve symbols in dynamics nor reduce dynamics to symbols but advocates complementarity of description), renders a particular picture of language, in which symbols are understood as described above. This picture diverges both from the common intuitive folk knowledge about language and the one present in the traditional theories (such as generativist theory). I will briefly (and in a simplified way) describe these common assumptions and claims that diverge the most from the theory of language as a system of replicable constraints, and point to the ways they might have skewed our thinking about language and prevented seeing more fruitful ways to study it, which are, in turn, enabled by the alternative view.

**Language as a System of Replicable Constraints**

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**Table 1: Symbol: Redefinition (Continued)**

<table>
<thead>
<tr>
<th>Symbol in a Formal System</th>
<th>Symbol as a Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbols are structures that substitute (map onto) something else. Semantics of symbols is in the mapping relation between a set of forms and a set of meanings (traits or referents)</td>
<td>Symbols are structures that control dynamics. It is difficult to predict the outcome of their action (meaning). Meaning is always underspecified which means that mapping relation is not possible (or can only be an approximation)</td>
</tr>
<tr>
<td>Mapping or referring relation is a binary (0 or 1) relation</td>
<td>Constraints on dynamics may have different strengths (leaving different role to contexts)</td>
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**Forms of Language Do Not Map onto Meanings**

Most theories of language accept that language is a system of formal symbols that are about something due to a mapping relation between form and meaning. Symbols of natural language refer to things in the world or ideas in the head. Therefore linguistic processing is about something (has meaning) because at any moment one can substitute this something for a given symbol, or map the content onto a symbol.  

**Alternative view:** If symbols are understood as constraints on dynamics, then it is not possible that the relation between a symbolic form and its meaning is the one of mapping. Mapping is a relation between two sets of identifiable elements. The relation of constraining does not offer this feature (identifiability of elements) on the side of symbol’s action. Symbolic forms are distinguishable entities, but the dynamics they constrain is different every time the constraining happens. Systems in which the symbolic forms are immersed are complex and dynamical: The effects of a symbol’s action may be vastly different depending on the state of the system at a given moment and may change non-linearly depending on a number of other variables impinging on the system. Think about a peg in a flow of fluid: It will disturb the flow, creating vortices. The vortices will be a bit different each time they form, and vastly different if the speed of the flow and the viscosity of the fluid changes.
However if mapping is not a good way to characterize the relation between form and meaning then substituting cannot be the process that gives meaning to symbols. The proposed constraining relation, which links symbols to their meaning, is much more complex than mapping. First, symbols work as constraints not only in an individual here and now. Constraining happens also with respect to dynamics of a conversing dyad, or other interactions (e.g., Jennings & Thompson, 2012; Cowley, 2011) and on time scales longer than the on-line scale (most notably in development). Second, unlike the relation of mapping, or referring, the relation of constraining is not all-or-none. Constraining can be strong, for example, almost unequivocally and independently of context specifying the referent (e.g., Barak Obama) or can be weak, constraining only some aspects of potential meaning, leaving a lot for the individual and contextual dynamics (e.g., deictic here).

The Structure of Language Is Not Exclusively Due to the Individual Cognitive Machinery
In the approach that informed the last several decades of psycholinguistics, language is treated, above all, as an individual cognitive skill: Individuals possess cognitive machinery, which generates all grammatical and none of the ungrammatical sentences of one’s native language (save the performance constraints).

*Alternative view:* It is true that individuals are the source of the physical stimuli that have constraining power. Yet their production is crucially dependent on: i) being in a certain situation here and now, and ii) being prepared, or tuned for linguistic and—more broadly—social interaction both in evolution, acculturation and development. From this perspective language becomes, above all, a way of physical and cognitive coordination. The primacy of the individual in explanations may obscure the natural collectivity, the primacy of we (see Rączaszek-Leonardi & Cowley, 2012) that lies at the basis of communion or synergy formation. In other words, rather than being a machine in individual’s head, language is seen as a system of constraints for controlling collectivity, providing means for flexible coordination of elements into functional wholes. Obviously it does so by controlling individuals, but the level of interaction becomes a crucial one for selection of linguistic structures.

Linguistic Communication Is for Coordination Rather Than Understanding
A general tendency of the good old-fashioned cognitive sciences to think about cognition as being for understanding the world instead for acting it the world manifests itself also in the cognitive science of language: People communicate through language in order to understand each other. Even in the approaches in which the importance of the dialogical nature of language is recognized, linguistic communication is still viewed as passing information from a speaker to a hearer, in order for it to become common, identical information present in both heads. The goal of communication is to equalize the world models of speakers and hearers (e.g., Pickering & Garrod, 2004).
**Alternative view:** In the view of language as social coordination (e.g., Rączaszek-Leonardi & Cowley, 2012) the functional aspect of communication comes to the fore. Paraphrasing Novalis: We will never understand each other but we can do much more than that. People communicate in order to do things together, which only sometimes necessitates identity of reference and/or full likeness of mental models of the situation. Starting with Malinowski’s phatic communication, in which these identities do not seem crucial at all, to task-dependent dialogues in which as long as the actors’ moves in the situation are proper and relevant to the task’s goal no one really cares for identity. An important consequence of this coordinative view of the function of language is that often coordination in realizing a task, that is, functional coordination requires that the roles of the participants are not identical but rather divided, complementary with respect to the task. In order for a proper division of labour to happen, it is more beneficial that the participants’ knowledge, skills and perspectives on crucial aspects of the task are not identical (Rączaszek-Leonardi, 2009). Thus what counts, besides common ground, is the pooled ground that makes dyads or groups more efficient than individuals.

**Studying Linguistic Meaning Requires Studying Dynamics**

In connection to the first point about mapping, the mechanism for meaning transfer (or equalizing) between individuals in the process of understanding each other depends almost exclusively on the exchanged words or expressions. Thanks to the mapping relation, meaning in the head of A and B can be gradually equalized by words carrying the elements of meaning from the speaker to the hearer.

**Alternative view:** As pointed out above, the redefinition of symbols as constraints, not containers, changes the definition of meaning of linguistic forms. Congruent with earlier works concerning the symbol-grounding problem (Searle, 1980; Harnad, 1990), according to which the syntactic level of language is not sufficient to account for what language is about, here it is clear that the level of linguistic forms will not constitute an independent explanation. As Pattee writes (1987, p. 337): “it is useless to search for meaning in symbols without complementary knowledge of the dynamics being constrained by the symbols.” The prevalent (Sperber & Wilson, 1986) picture of communication as meaning transfer from person A to B via encoding it in sounds by A and decoding by B does not fit the account. Meaning, rather than being transferred, is made anew in communication, by letting symbols constrain the existing dynamics. Thus in this view on language, the crucial part of specifying the meaning of linguistic expressions is left to existing dynamics of cognitive and coordinative processes: “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, 1982b, p. 23).

In summary, the characterization of language as a formal symbolic system certainly facilitates some aspects of its study, but at the cost of obscuring fruitful ways to study its vital functions. It takes dynamic events out of the picture, giving the entire explanatory burden to mental symbolic representations. Seeing symbols as
constraints, not vessels for meaning, opens new perspectives but also poses new challenges. In such a view of language, the theory of meaning becomes much less clear-cut and elegant than in the traditional view, where it could be described by intension or extension of a concept with a given linguistic label. One needs to know the system (or rather systems) in which the constraints emerged and know the time scales of changes in these systems, in order to understand how linguistic symbols constrain the existing dynamics.

Selected Time Scales and Systems in the Study of Language

Already a decade ago, researchers realized that processes pertinent to linguistic and psycho-linguistic phenomena observed in the here and now unfold at many different rates (MacWhinney, 2005; Rączaszek-Leonardi, 2003; Smith, Brighton & Kirby, 2003, 2005). The time scales involved span a wide range of values, from milliseconds of neural events; milliseconds and seconds of individual cognitive events and interactions; hours and days of previous social commitments and social relations; weeks, months and years of language development (ontogeny); years and centuries of cultural language evolution (diachrony); and thousands and millions of years of biological evolution. Relevant events, unfolding on these different time scales concern different systems: from subsystems in the individual brain and body, to individuals, to dyads, groups and populations.

Which time scales and systems are the focus of attention depends, obviously, on the research questions asked by a subdomain of language sciences; however, one has to remember that separation of any given system and/or any given time scale might not be feasible: Integrated constraints from all of them act on an individual at any given moment. The framework presented above may, as said before, help to put some organization in this picture of forces, based on the view of symbolic forms as selected functional constraints. An important benefit is that letting dynamics into the picture makes this framework naturally link with some branches of newly developing approaches in cognitive sciences: that of embodied and distributed cognition. Research within these approaches already began to uncover some characteristics of the dynamics on several interesting time scales and systems.

Here I briefly describe selected time scales and mention relevant research and research directions. The list below does not strive to be exhaustive. As Enfield (2013) rightly says: There is no definitive set of frames, as new ones may emerge once we find a system of causally linked elements whose changes might be relevant for the study of language.

Biological Evolution Time Scale

On this time scale, transmittable genetic material is selected, which controls (environmentally dependent) dynamical events responsible for phenotype construction. This is the scale on which, in Gibson’s words senses become perceptual
From the point of view of language study the crucial aspect is that tuning is not only to action but also to co-action with conspecifics in the environment. Perception-action systems seem indeed to be tuned to upholding non-specific interaction (a kind of social glue), by evolving mechanisms that bind together elements of social systems. Research on biological preparation for interaction is usually performed within developmental cognitive psychology, where the underpinnings of early learning processes are identified. This biological preparation seems to involve innate biases for focusing on the other, especially the face and eyes (Field, 1982, Farroni, Mansfield, Lai, & Johnson, 2003), innate synchronization (Murray & Thevarthen, 1985; Nadel, Carchon, Kervella, Marcelli, & Reserbat-Plantey, 1999) and imitation (Field, 1982; Meltzoff & Moore, 1977; Nagy, 2006). It is possible that predispositions for certain granulation of distinguishable auditory stimuli and sequence processing skills also belong to the specific tuning for language use.

Other research on language that tackles this time scale explores possible consequences for language evolution of the processes on other time scales, such as perceptual and ontogenetic. Due to the methodological constraints these involved mainly computer simulations (Smith, Brighton & Kirby, 2003) but recently also includes experimental semiotics, which study, for example, the influence of the type of medium on the kind of communicative systems developed (Galantucci, Kroos & Rhodes, 2010), or the properties of cognitive structuring on the emergence of regularities (Cornish, 2010). This program links also to the next time scale of the cultural evolution of language.

Cultural Evolution Time Scale
Events pertinent to language on this scale have been studied for over a century under the term diachrony. In the view advanced here, language is an important element of a cognitive niche (Laland, Odling-Smee, & Feldman, 2001; Clark, 2006). On this time scale language changes under pressures from the interaction (efficiency of) and individual (economy of production/detection, learnability) levels (see, e.g., Lupyan & Dale, 2010), which serve as criteria for structure selection. Language thus has the power of stabilizing new patterns of individual and collective behaviors much faster than biological evolution, which adapts phenotype to environmental changes. Anthropological focus on how language intertwines with social practice provides a valuable window on the mechanisms behind this stabilizing power (see, e.g., Sidnell & Enfield, 2012; Sinha, in press).

Ontogenetic Time Scale
Flexibility of human cognition depends on perception-action system being further tuned for interaction and specifically for language use (Cowley, 2003; Rączaszek-Leonardi, Nomikou, & Rohlfing, 2013). On the basis of the biological preparation for non-specific interaction, culturally established modes of coordination are shaped in
multiple episodes. These educate attention and responsiveness to cues from others. Language is learned in such episodes, by tuning the perception-action system of an individual to utterances of others as affordances for action and co-action (Linell, 2009; Worgan, 2010).

**On-line Scale of Cognition and Interaction**

This time scale is perhaps the most researched one because it is connected to conscious experience and because changes on this scale can be readily seen in the lab. According to the third way framework presented above, language consists of physical structures immersed in various kinds of dynamics. On this time scale the natural interactive dynamics that forms the fundament for language action is quite extensively studied. This involves dynamics of natural human synchronization and imitation in non-linguistic interactions (Turvey, 1990; Schmidt, Carello, & Turvey, 1990; Schmidt & Richardson, 2008; Riley, Richardson, Shockley, & Ramenzoni, 2011; for research on neural underpinnings see: Bekkering et al., 2009; Rizzolatti & Craighero, 2004; Tognoli, Lagarde, Deguzman, & Kelso, 2007; Dumas, 2011) as well as linguistic ones (Shockley, Santana, & Fowler, 2003; Dale, Kirkham, & Richardson, 2011). Language both uses bodily-established dynamics, as well as creates specific new ones, as we entrain in syllable rate (Wilson & Wilson, 2005), fundamental frequency and specific turn-taking patterns. Concrete linguistic forms (thanks to their cultural-evolutionary, ontogenetic and experiential history) are then able to steer this basic dynamics into task- and situation-relevant directions (Rączaszek-Leonardi & Cowley, 2012; Fusaroli et al., 2012; Fusaroli, Rączaszek-Leonardi, & Tylén, 2014).

**Social Events Time Scale**

Several researchers who acknowledge this multisystem and multiscale nature of language point to yet another crucial time scale which may be difficult to discern because its clock does not tick according to an established time-unit but rather to particular moves in a sequence of social events. This is called sequence time by Goffman (1981, see Enfield, in press), *social scale* (MacWhinney, 2005) or *enchronic frame* (Enfield, in press). Meaningful social interactions can be spread in time, preserving its structure, being organized around social values (Enfield, 2013). The ability of humans to rely on perception and memory for such sequences was proposed by Donald as an adaptation for acting in distributed cognitive networks, based on a hypothetical neural process (the *slow process* [Donald, 2007]). If this scale is also acknowledged, it is evident that at any given moment a human being is enacting multiple such structures, that is, that her behavior is constrained, in parallel, by many forces not readily visible here and now (i.e., at the on-line scale of action or interaction).

Other important scales have been mentioned in the literature (for a review see Enfield, 2013; for a discussion of alternative systematizations see Steffensen & Pedersen, 2014). The picture is complicated further by the fact that events unfolding on those different time scales are not independent (Rączaszek-Leonardi, 2009, 2010).
For example, it is the effectiveness of coordination and learnability that decide which structures remain in language on the cultural evolution time scale. On the other hand, the dynamics of here and now, which is harnessed by the structures uttered, is already shaped—both on evolutionary and ontogenetic time scales and both on the individual level of acting in the environment as well as on the level of interaction. Thus, at any given moment, human cognitive system is a point that lies on trajectories of many nested systems, changing on multiple time scales.

**Dealing with Complexity: Theory of Language in the Form of a Computer Simulation**

One way to deal with such complexity of an explanatory theory is through a computer simulation (Cangelosi & Parisi, 2002). In the case of phenomena, in which causal loops are contained on multiple time scales and dependent on iterative nonlinear processes, this form of theory allows for testing models and studying the role of parameters. It is very important, however, to emphasize the difference between theories that are based on such simulations and theories as computational algorithms, such as those which were advocated as model psychological theories at the beginnings of cognitive sciences by, for example, Newell & Simon (1976). It is the modern computer’s ability to model stochastic, dynamical, nonlinear, interactive, iterative and nested processes that is the key property on which the theory creations rest, and not the ability to compute according to a preestablished sequence of steps in an algorithm.

**Limits of Predictability**

The theory in such a form, that is, a simulation of dynamics on various time scales, which is harnessed by emerging and selected symbolic structures, is inevitably limited in its predictability (Rączaszek-Leonardi, 2014). Even if theorists from various sub-disciplines studying language could identify all the relevant time scales and systems, and in a common effort could specify the connections among the time scales and systems, the workings of constraints would still be impossible to predict. This is because constraints are imposed on processes that are dynamic, sensitive to initial conditions and small perturbations, and because the constraints are outcomes of an irreversible selection process. Each one of such processes is thus idiosyncratic, and their generalizability into laws and regularities is limited. Obviously, generalizability and regularity description is possible and desirable, but it is important to keep in mind that in such a system they are only approximations of the workings of the underlying dynamics. This means that they are not lawful generalizations—the regularities always can be violated if the dynamics so dictates. Dependency on history, on irreversible selective processes makes these generalizations different in kind from those used in formulating laws of physics.

It is symptomatic that one of the key founders of theoretical bases for the computer metaphor of the mind, in his later work on the processes of morphogenesis, wrote:
Most of an organism, most of the time, is developing from one pattern into another, rather than from homogeneity into a pattern. One would like to be able to follow this more general process mathematically also. The difficulties are, however, such that one cannot hope to have any very embracing theory of such processes, beyond the statement of the equations. It might be possible, however, to treat few particular cases in detail with the aid of a digital computer. This method has the advantage that it is not so necessary to make simplifying assumptions as it is when doing a more theoretical type of analysis. ... The essential disadvantage of the method is that one only gets results for particular cases. (Alan Turing, 1952, pp. 71-72; emphasis mine)

This dependence on “results for particular cases” which, at best, give fuzzy classes of solutions—some of the time—show where the limits of predictability are. Models of language, as a system of replicable constraints, suffer from—or are blessed with—the same limitations. Perhaps the claim about the irreducibility of historical trajectories of language processes to deterministic paths is rather obvious. However reaching this claim from the direction motivated by discovering the significance of dynamics in symbolic processes, gives a place for symbols in these dynamics and perhaps leads to a better understanding the sources of this unpredictability on one hand and the necessity for it on the other.

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