Natural languages as complex adaptive systems

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Abstract
Certain basic properties of complex systems are compared to those of communal languages. It is argued that languages are comprised of interacting units that constitute a functioning whole, with the properties of network structure, decentralized control, emergence, reciprocal causation, far-from-equilibrium state, and positive and negative feedback processes. The possibility that languages also have the property of adaptivity is also discussed. The key problem in defining language adaptivity is found to be the role played by individual linguistic variation in maintaining a language's stability and capacity for change. It is argued in conclusion that considering natural languages as complex adaptive systems serves as a basis for hypotheses that can be modeled and tested empirically, and that the complex systems approach can bring a unity and coherence to the understanding of diverse linguistic phenomena. (Fapesp 2013/11525-7)

Keywords: complex systems; linguistics; adaptation; sociolinguistic variation.

Línguas naturais consideradas como sistemas complexos adaptativos

Resumo
Certas propriedades básicas de sistemas complexos são comparadas com as de línguas naturais. Argumenta-se que as línguas são compostas de unidades que interagem e compõem um todo em funcionamento com as propriedades de estrutura de rede, controle descentralizado, emergência, causalidade recíproca, estado longe de equilíbrio e processos de *feedback* positivo e negativo. Também é discutida a possibilidade de que as línguas têm a propriedade de adaptabilidade. O problema principal em definir a adaptabilidade da linguagem é tido como o papel desempenhado pela variação linguística individual na manutenção de uma estabilidade e capacidade de mudança da linguagem. Para concluir, argumenta-se que considerar as línguas naturais como sistemas adaptativos complexos serve como base para hipóteses que podem ser modeladas e testadas empiricamente, e que a abordagem de sistemas complexos pode trazer uma unidade e coerência para a compreensão de diversos fenômenos linguísticos. (Fapesp 2013/11525-7)

Palavras-chave: sistemas complexos; linguística; adaptação; variação sociolinguística.

Introduction

This article begins with a brief review of past and current applications of complex systems theory in linguistics. The following section compares certain properties of complex systems to properties of natural languages, showing how languages may be considered to be such systems. In the section after that, the question of whether languages are adaptive systems is discussed. The article concludes with some observations on the usefulness to linguistic theory of the complex systems approach.

The application of complex systems theory in linguistics is relatively recent and, judging from the number of academic publications in the field, one may say that it began in the mid-1990s. Before that time, the matter was addressed in a few scattered publications or in specialized areas of research unfamiliar to most linguists. In the 1960s, the Russian linguist Roman Jakobson argued that languages are dynamic, self-regulating, teleonomic systems (JAKOBSON, 1990, p. 474, 483), but he did not develop his ideas on the subject into a detailed linguistic theory. At around the same time, the French mathematician René Thom applied his catastrophe theory to semiotics, and his ideas were later taken up by others and developed into "catastrophist" models of various aspects of language (WILDGEN; BRANDT, 2010). Systemic concepts have also been applied in quantificational linguistics, an area that has its roots in Zipf's work in the 1930s and 1940s on power-law distributions (KÖHLER; ALTMANN, 2005; NARANAN; BALASUBRAHMANYAN, 2005). Quantificational linguists in Germany developed a theory of "synergetic linguistics" in the 1980s, and research in this field continues to the present day (KÖHLER, 2005). These proposals, and others like them, have so far had no more than marginal influence on mainstream linguistics.

However, within the last twenty years, an ever-increasing number of articles and books have appeared that deal with one or another aspect of language from the complexity perspective. Many of these works have come from the applied linguistics field. This field, which deals with first and second language learning, discourse phenomena, and language teaching, has developed theoretical concepts that, in some ways, have distanced themselves from developments in general linguistic theory (LARSEN-FREEMAN; CAMERON, 2008; DE BOT et al., 2013). Another area in which complex systems theory has been extensively applied is that of language evolution, which in its current form studies the evolution of language as both a biological and cultural process. Because of the lack of historical data and the complexity of the interactions involved, computational modeling has come to play an important role in this research field (ZUIDEMA; DE BOER, 2013). The issue of the comparative complexity of languages and specific types of linguistic structures, long ignored by linguists because of its association with 19th century theories that attributed superiority to European languages, is now beginning to be addressed by scholars in a contemporary scientific context (SAMPSON et al., 2009). Within the traditional areas of linguistic theory, a few broad-based discussions of complex systems and language have appeared, all within the last ten years (LARSEN-FREEMAN; CAMERON, 2008; BECKNER et al., 2009; KRETZSCHMAR, 2015). Other specialized linguistic areas in which problems have been addressed from the complexity perspective are phonology (WEDEL, 2011), syntax (BOECKX, 2014), historical linguistics (EHALA, 1996; KELLER, 1994), dialectology (KRETZSCHMAR, 2009), cognitive linguistics (BERNÁRDEZ, 2008; FRANK; GONTIER, 2010), and psycholinguistics (DE BOT, 2012; RACZASZEK-LEONARDI, 2014).

Overall, current research in linguistics from the complex systems perspective is still characterized by disparate efforts in a wide range of language-related disciplines, and for each of these disciplines the complex systems perspective entails a reconsideration of fundamental concepts. Although general theoretical proposals have been advanced, no comprehensive theory of language based on complexity theory has been developed in detail and widely accepted so far. However, linguists are increasingly interested in complex systems theory because of its perceived ability to bring a unity and coherence of explanation to diverse linguistic phenomena, and to suggest hypotheses for investigation

that can be modeled and tested. This will be made clear in the following section, where some of the general properties shared by languages and complex adaptive systems are discussed.

Languages as complex adaptive systems

In this section, we will describe some well-known characteristics of complex systems (HEYLIGHEN, 2001, 2008) and show how languages can be understood as having these characteristics. It is important to note that here we are dealing with communal languages (languages considered as a property of a population), as opposed to idiolects (languages considered as properties of individuals). In the section that follows the present one, we will deal with the question of whether languages adapt, as well as with the question of how individual differences fit into a broader definition of communal languages.

Complex systems are composed of units in dynamic interaction, whose interdependency provides to the whole system a functional character. The units interact with each other on the local level, but this local interaction supports the larger system as a functioning whole. Human languages are dynamic systems, the units of which are individual speakers of a language. Interaction in conversation is a local activity in which speakers' actions are highly interdependent; this activity may be considered on various timescales (brain activity, immediate conversational setting, personal relationships, cultural processes, multi-generational language change) (LARSEN-FREEMAN; CAMERON, 2008, p. 166-169, 240-241). At the communal level, which also may be looked at in terms of different timescales, a language system as a whole functions to coordinate speakers' activities over large stretches of space and time.

The interaction of units in a complex system can be defined as a network structure and modeled mathematically and computationally. Some complex networks have special characteristics (scale-free, small-world, clustering), and these and other network properties have been applied to the analysis of social networks of various types (EASLEY; KLEINBERG, 2010). Human interaction through language is essential to social network formation. Sociolinguists have discovered that the use of certain elements of speech (sociolinguistic variations) in a language tend to correlate with age, class, and gender. Researchers in this area have also found that sociolinguistic variations and their social correlates correspond to social networks. The computational modeling of such phenomena is now being explored by researchers (e.g., FAGYAL et al. 2010; MÜHLENBERND; QUINLEY, 2013). A multilingual individual naturally participates in several language networks, and the use of different languages in multilingual communities is also susceptible to modeling (e.g., MINNET; WANG, 2008).

Control in complex systems is distributed throughout the units that make up the system. No external controller, single unit, or group of units within the system guides the actions of the system. Languages are a good example of distributed control. They have evolved over time by means of the collective interaction of many generations of speakers, and presumably no individual Adam or group of founding fathers created the vocabulary and grammar of any natural language. Efforts to regulate change in language (for example, by authorities such as national language academies) are notoriously ineffective.

The interaction of the units of a complex system results in the appearance of emergent properties over time. These are properties of the system as a whole that cannot be

explained only in terms of (or 'reduced to') the activities of the individual units of the system, but nevertheless come into being, or emerge, as a result of the interaction of the system's units. Beckner et al. (2009, p. 15) state the core hypothesis of the complex systems approach to language: "An idiolect is emergent from an individual's language use through social interactions with other individuals in the communal language, whereas a communal language is emergent as the result of the interaction of the idiolects". For these authors, computer modeling can help to overcome the insuperable difficulties of studying communal language emergence in large populations over long periods of time (and often with little or no historical evidence); it "allows one to prove, at least *in principle*, that specific fundamental mechanisms can combine to produce some observed effect" (BECKNER et al., 2009, p. 12).

'Usage-based' theories of language, whose proponents constitute an important school of thought in linguistics, propose explanations of language acquisition, language structure, and language change, which do not rely on the assumption of highly specific and restrictive innate language-specific capacities in the brain. The concept of emergence is useful in this area of study because it provides a way of understanding how complex language structures could have evolved through human activity involving general cognitive capacities such as memory and imitation. The appeal of complex systems theory for researchers in this area is that it provides a unifying framework for usage-based explanations, and most linguists who adopt the complex systems approach do so based on usage-based approaches (e.g., LARSEN-FREEMAN; CAMERON, 2008; BECKER et al., 2009). Within linguistics, "emergentism" refers to a range of research approaches that make use of the general concept of emergence but accept the broader complex systems approach in varying degrees (MACWHINNEY; O'GRADY, 2015).

Although complex systems exist as a result of, and are in a sense caused by, the individual activities of their units, emergent properties can restrict the activity of the units in a system and thus cause them to behave differently than they would otherwise ('reciprocal causation': LARSEN-FREEMAN; CAMERON, 2008, p. 59). On the one hand, this two-way process is seen in the fact that individual linguistic innovations, if they are imitated by others and spread through a language network, may contribute to change in a language. On the other hand, an individual's linguistic behavior is restricted by the language he or she speaks – a language is a norm that one must follow in order to communicate.

Complex systems exist in a far-from-equilibrium state in which there is a constant flow of energy among the units of the system and between the system and its environment; such systems cease to exist when their source of energy is removed. Without attempting to make a strict analogy between social systems and physical or biological systems, it may nevertheless be observed that languages disappear completely when their speakers (considered as the source of a language's energy) die or switch to another language. Like the dissolution of a whirlpool, the death of an organism, or the extinction of a species, the initial conditions and subsequent interactions that lead to the emergence of a language are too complex to be recreated or reconstructed in an exact manner. Thus, it is no surprise that the loss of language diversity in the world has often been compared to the irreparable loss of species diversity in ecosystems.

Feedback processes are another main characteristic of complex systems. In complex systems, negative feedback within a network dampens perturbations and thus allows

a system to maintain stability; positive feedback reinforces perturbations so that they reverberate through a system, bringing about changes which, if uncontrolled, could cause instability to the system. In complex systems, positive and negative feedback interact to allow the system to maintain stability, while, at the same time, giving it flexibility to respond to changes in the environment. The entry of an innovation into a language, such as a new word, grammatical construction, or pronunciation, can be thought of as a process involving positive and negative feedback in a network of speakers. Some innovations are picked up and repeatedly imitated (positive feedback) by only a small intimately related group of people, such as a family or clique, and fade into disuse (negative feedback) after a relatively short time. Other innovations may spread to the point where they become the common equipment of most language users. The constant rising and falling tide of the use of such linguistic features is an important aspect of language change.

Because of feedback processes, complex systems can display non-linear behavior: a small perturbation, reinforced by positive feedback, can cause a large change in the system; a large perturbation, dampened by negative feedback, can cause little change. Due to the complexity of the factors involved, the exact behavior of such systems can be extremely difficult to predict. Larsen-Freeman and Cameron (2008, p. 85-88) argue that non-linearity can be seen in the relatively abrupt historical 'restructuring' processes that often take place in languages.

Adaptation: Do languages adapt?

The way that complex systems maintain a balance between inflexible stability and uncontrolled change is through adaptation. Although the terms "complex systems" and "complex adaptive systems" are often used synonymously, adaptivity, strictly speaking, is a property of only some complex systems. In the case of languages, a mixture of stability and change is evident from the fact that languages change at a rate that is much faster than human biological evolution, but much slower than cultural development. Language change has been an important subject of investigation in linguistics for two hundred years, but at present there is no widely accepted theory as to its causes. Comparisons between language change and biological adaptation were proposed in the wake of Darwin's theory of natural selection, but were controversial in linguistics during the 20th century; most linguists at present reject such comparisons (LABOV, 2001, p. 6-15). In recent decades, however, theories of language adaptation have been reintroduced into linguistics in the new scientific contexts of contemporary evolutionary theory, mimetics, and complex systems theory (CHRISTIANSEN; CHATER, 2008; CROFT, 2000; MUFWENE, 2001; BECKNER et al. 2009). The complex systems perspective implies that languages adapt to their environments in some fashion.

According to Heylighen (2001, p. 15), adaptation may be seen as a "fit" between a given configuration of a system and a given configuration of its environment – that is, the system is able to maintain itself and grow under specific circumstances (also note that a complex system may itself be considered as the environment to which its subsystems and units are adapted). However, changes in the environment can make a system unstable and lead to its disintegration. The way an adaptive system maintains itself in the face of changes is

> [...] by counteracting perturbations before they become large enough to endanger the essential organization. This means that the system must be able to: 1) produce a sufficient variety of actions to cope with each of the possible perturbations (Ashby's 'law of requisite variety'); 2) select the most adequate counteraction for a given perturbation. (HEYLIGHEN, 2001, p. 15).

In the approach described by Heylighen, the concepts of variation and selection are provided with abstract definitions that apply to complex adaptive systems in general, and which subsume the concept of biological species adaptation. A system's possibilities for alternative actions must be numerous enough to provide the necessary variation, but limited and stable enough so that a choice (selection) between them can be effectively achieved. For this reason "[...] complex adaptive systems tend to reside on the 'edge of chaos', that is, in the narrow domain between frozen constancy (equilibrium) and turbulent, chaotic activity" (HEYLIGHEN, 2001, p. 16). 'Survival of the fittest', on this interpretation, refers to a situation where the environment itself 'selects' which actions of the system achieve a fit and which do not.

It is not difficult to imagine that an individual may be understood as adapting to his or her linguistic environment through lifelong processes of linguistic development. On the collective level, however, finding an appropriate linguistic analogy for system adaptivity is more difficult. It is clear from the discussion in the previous section that languages manifest the stability plus change that is typical of complex systems. But if languages adapt on the collective level, what is the environment they adapt to?

For the psycholinguists Christiansen and Chater (2008), language has adapted to the human brain. Arguing against the idea that an innate capacity for language could have evolved in humans through biological processes of natural selection, they claim that languages, considered on the collective level, came into being and continually change by adapting to their environment like biological species. In the case of languages, however, adaptation is a cultural process and not a biological one; the brains of human beings are the environment to which languages have adapted. For the authors,

> […] the structure of human language must inevitably be shaped around human learning and processing biases deriving from the structure of our thought processes, perceptuomotor factors, cognitive limitations, and pragmatic constraints. Language is easy for us to learn and use, not because our brains embody knowledge of language, but because language has adapted to our brains. (CHRISTIANSEN; CHATER, 2008, p. 490)

This argument may be expanded to include not only the brain, but the entire body as well, as scholars in the area of sign languages have pointed out (ARONOFF et al., 2008).

However, this argument is only concerned with the most constant aspect of the environment to which languages must adapt, that of the human body considered as a biological organism. The other aspect is that of the culturally situated daily activity of individuals, which is characterized by great variety and rapid change. In order to address the question of how languages can be thought of as adapting to this aspect of their environment, it will be useful to first consider how linguistics traditionally conceives of what languages are. However, it should be noted that, within linguistics, there is so far no consensus on this important point. For the purposes of this discussion, we shall briefly consider two conceptions of language that have been extremely influential, those of Saussure and Chomsky.

For Saussure (1986), language has both a social aspect (*langue*) and an individual aspect (*parole*). Saussure argues that linguistics should study *langue*, which is "the social part of language, external to the individual, who by himself is powerless either to create it or modify it" (SAUSSURE, 1986, p. 14). With regard to this aspect of language, Saussure says: "A language, as a collective phenomenon, takes the form of a totality of imprints in everyone's brain, rather like a dictionary of which each individual has an identical copy" (SAUSSURE, 1986, p. 19). *Parole*, on the other hand, consists in acts of thought and speech which are "individual and ephemeral" (SAUSSURE, 1986, p. 19). Saussure believes that *parole*, which deals with individual psycho-physical processes, is too heterogeneous to be the object of a science of language.

Chomsky (1986) makes a distinction with a very different focus. For Chomsky, the proper object of linguistic study is I-language ("internalized", "individual"), "the system of knowledge of language attained and internally represented in the mind/brain", which is a product of innate capacity plus experience (CHOMSKY, 1986, p. 24). E-language ("externalized"), on the other hand, consists in "the actual or potential speech events (perhaps along with some account of their context of use and semantic content)" (CHOMSKY, 1986, p. 20). E-language, which Chomsky calls an "epiphenomenon at best" (1986, p. 25), includes collective phenomena such as historical change and sociolinguistic variation.

Despite their differences, it is common to both viewpoints that variation among individual speakers of a language – although acknowledged as existing – is not essential to defining specific languages or language in general. Furthermore, in both approaches, language systems are understood as grammatical and phonological structures isolated from their use in conversation and in specific contexts. Although the usage-based approaches mentioned earlier reject the strict distinction between language system and language use, such approaches are not necessarily incompatible with the notions of *langue* or I-language, and linguists who adopt usage-based perspectives differ in the degree to which they accept these concepts (CROFT, n.d.). However, regardless of these differences, a basic premise of usage-based approaches is that the hows and whys of individual acts of speech are essential to any explanation of what languages are. Usage-based approaches to language are thus compatible with complex systems theory for, among others, the following reason: from the complex systems perspective, although the individual units in a system may be ignored in the sense that macro-level processes can be described statistically and explained in terms of general principles of complex systems theory, it is still assumed that these processes have their basis on the micro-level in specific local interactions of the system's units, and that these micro-level interactions also require explanation if the system as such is to be properly understood.

One of the great achievements of linguistics in the second half of the twentieth century is the discovery by researchers in the sociolinguists field that variation among the speakers of a language is much more extensive than was formerly believed, and that there are systematic correlations between variant linguistic forms and social divisions based on age, social class, gender, and other groupings on smaller scales. However, the sociolinguistic perspective (at least in its North American form) generally sees socially-related variation as indicating that speakers within a social subgroup share a common language system (in the sense of *langue*) that differs from that of other subgroups, though perhaps only in certain rules or features. Thus, even in this area, in which empirical study in collaboration with community members is emphasized, "sociolinguists take an interest in

what people say not for their personal language behavior, but as individuals who may be chosen to represent collectivities (speech communities) that are assumed to exist. Sociolinguists are interested in 'the most systematic form of the language,' before it can be deflected by the messy details of human social organization" (KRETZSCHMAR, 2009, p. 10).

Given the above definition of adaptivity, it may be suggested that languages in some way or other have evolved a variety of responses (alternative forms, as seen in social, regional, and even individual variants found in a population) that are sufficient for a language system to maintain itself in the face of the variety of perturbations found in its environment (constant interaction among individuals); it also follows that there should exist some factor, whether inside or outside the language system, that selects adequate responses for given situations. This idea, however, is not in accord with the traditional notions of language system. For Chomsky, the systematic aspect of language is ultimately based on innate capacities. The notion of I-language denies that "external" factors such as conversational interaction and historical change are constitutive of language and essential to its definition. Saussure does not deny this fact, but assumes that *langue* can be defined and studied separately, and that individual differences are peripheral to the description of a language system; sociolinguistics accepts this Saussurean assumption in a refined fashion.

Therefore, in order to define language adaptation, a different definition of language is needed, one that not only supposes that micro-level interaction leads to the emergence of macro-level structures and processes, but one that connects observed variation in speech to the theoretical notion of variety and selection in complex adaptive systems. Kretzschmar (2009, 2015), working from the complex systems perspective, has made great progress in this direction with his "linguistics of speech" (i.e., of *parole*), in which languages are conceived of as consisting of features (sets of variant speech forms that share the same meaning); these variants, alternative ways of saying the same thing, flow through a population of speakers somewhat like genes in the gene pool of a biological species. Individual speakers 'select' variants in the sense that they choose to use them (or not) in given situations; the language system 'selects' variants only in the sense that, due to feedback effects within the language system network, a given variant may increase or decrease in frequency (or even disappear) within a population.

Kretzschmar (2009, 2015) demonstrates that feature variants display a scale-free "A-curve" (power law) distribution of frequency over geographic areas (i.e., there are very few highly frequent variants of a feature, and very many infrequent variants). The frequency distributions are scale-free in the sense that no matter the social grouping or the size of the area considered, the A-curve pattern remains constant even though the relative frequency of specific variants may differ among area or group samples. One consequence of this scale-free distribution of variants is that for any given point within a geographical area, an individual has a high probability of using the same highly frequent variants as his or her neighbors. Among individuals, this creates the impression that they speak a dialect particular to their region, and that people from other regions speak different dialects. However, regional differences among individuals are in fact a matter of gradual differences between adjacent local networks of speakers. Variants of a given feature are not found in neat compact geographical areas, nor do groups of different features share geographical distribution. An essential aspect of language dynamics is missed if one assumes that the most frequent variants found within a certain geographical region (of any

size) are indicators of a supposed common language system in that area. Kretzschmar (2009) notes that, by considering the most common variants as the systematic or normal ones, a linguist could possibly end up producing a description of a language that nobody actually speaks.

The definition of adaptation stated earlier, as it applies to languages, may now be reconsidered. Selection, in terms of a language system (as opposed to selection of variants by individual speakers), may be thought of a process of survival of the fittest in an abstract sense. The environment external to the language system can be considered as the sum of the variety of situations in which the everyday language use of all speakers is situated; as Bernárdez (2008, p. 143-144) has observed "the constantly varying conditions of interaction, the basis of linguistic use, have variation as their immediate, inescapable consequence". Selection – that is, whether or not a variant propagates in a language network – depends on feedback processes within networks of speakers in which individual choices are heavily influenced by the choices of others. In this sense, it is a supra-individual process.

However, the concept of language adaptation still requires a definition of linguistic variation that is analogous to the systems theoretical concept of a variety of alternative actions available to a system. It is clear that there is much variation in languages, that conscious or unconscious innovations are a byproduct of the daily use of language, that speakers can make use of variations for their own purposes, and that the comparative frequency of variants of linguistic features may be expressed as A-curves (power laws). The question remains open as to how these facts fit in with the idea that a collective language system *must itself produce a variety of actions that maintain the stability of the system in the face of perturbations*. The development of clear and specifically language-related concepts of perturbation and variety of action would perhaps allow for the definition of a clear systems theoretical notion of language adaptation.[1] An important aspect of such a definition is that it would free the notion of language adaptation from metaphors taken from other disciplines, such as biology or economics.

Concluding remarks: the relevance of complexity theory for linguistics

The interrelatedness of systems concepts, when applied to language, brings a unity and coherence to the heterogeneous facts that Saussure believed could not be practically dealt with in a single science. By thinking of an individual speaker as both a complex system and an interacting unit in a greater dynamic system with emergent properties, it is possible to see the overall connections between individual language use, conversational interaction, social and regional variation, and language change. Researching these connections from the complexity perspective requires interdisciplinary collaboration, but the basic theoretical framework of complexity theory provides common ground for such ef-

[1] What Larsen-Freeman and Cameron say with regard to concepts in applied linguistics is directly relevant to the development of a clear concept of language adaptivity:
If we claim, for example, that 'interlanguage is a complex system', do we mean that interlanguage fulfils the criteria for being a complex system or that interlanguage is metaphorically like a complex system? What we need to be able to do, if complexity theory is to move past its metaphorical and bridging role, is to develop a field-specific classification: i.e. we need to be able to answer that question using criteria defined for the field of applied linguistics. (LARSEN-FREEMAN; CAMERON, 2008, p. 15).

forts. Applying complexity theory in linguistics has also opened up the possibility of creating a new definition of language that puts results from diverse language-related sciences into perspective, instead of artificially excluding them or forcing them into categories developed for other purposes.

Complex systems theory has shown itself to be a productive source of new ideas for linguistics. If one accepts the basic idea that languages are complex systems comprised of dynamically interacting units, then complexity theory becomes a basis on which predictions about language can be made. It can be predicted, for example, that networks of speakers have the properties of complex networks, that the control of their dynamics is distributed and decentralized, that they have emergent properties, and that they display processes of reciprocal causation and feedback. Adaptivity is an additional property of (some) complex systems that languages may be predicted to have. Arguments that languages have these properties have been presented above in a very general fashion. Specific predictive hypotheses that have been modeled and empirically tested are discussed in many of the bibliographic references given below.

BIBLIOGRAPHIC REFERENCES

ARONOFF, M.; MEIR, I.; PADDEN, C.; SANDLER, W. Open peer commentary: language is shaped by the body. *Behavioral and brain sciences*, v. 31, n. 5, p. 509-511, 2008.

BECKNER, C.; BLYTHE, R.; BYBEE, J.; CHRISTIANSEN, M. H.; CROFT, W.; ELLIS, N. C.; HOLLAND, J.; KE, J.; LARSEN-FREEMAN, D.; SCHOENEMANN, T. Language is a complex adaptive system: position paper. *Language Learning*, v. 59, s. 1, p. 1-26, 2009.

BERNÁRDEZ, E. Collective cognition and individual activity: variation, language and culture. In: FRANK, R. M. et al. (eds.). *Body, Language and Mind*. v. 2. Berlin: Mouton de Gruyter, 2008. p. 137-166.

BOECKX, C. *Elementary Syntactic Structures*. Cambridge: Cambridge University, 2014. 222 p.

CHOMSKY, N. *Knowledge of Language:* Its Nature, Origin, and Use. New York: Praeger, 1986. 307 p.

CHRISTIANSEN, M. H.; CHATER, N. Language as shaped by the brain. *Behavioral and brain sciences*, v. 31, n. 5, p. 489-509, 2008.

CROFT, W. *Grammar: functional approaches*. n. d. Available at: <http://www.unm.edu/~wcroft/Papers/Functionalism-IESBS2ed.pdf>. Accessed on: 4 Oct. 2015.

_____. *Explaining Language Change*. Harlow: Longman, 2000. 287 p.

DE BOT, K.; LOWIE, W.; THORNE, S. L.; VERSPOOR, M. Dynamic systems theory as a comprehensive theory of second language development. In: MAYO, M. et al. (eds.). *Contemporary Approaches to Second Language Acquisition*. Amsterdam: John Benjamins, 2013. p. 199-220.

DE BOT, K. The end of psycholinguistics as we know it? It's about time! In: JUDIT, N. et al. (eds.). *Mentális folyamatok a nyelvi feldolgozásban* (Mental Procedures in Language Processing). Budapest: Tinta Könyvkiadó, 2012. p. 10-19.

EASLEY, D., KLEINBERG, J. *Networks, Crowds, and Markets*. Cambridge: Cambridge University, 2010. 744 p.

EHALA, M. Self-organization and language change. *Diachronica*, v. 13, n. 1, p. 1-28, 1996.

FAGYAL, Z.; SWARUP, S.; ESCOBAR, A. M.; GASSER, L.; LAKKARAJU, K. Centers, peripheries, and popularity: the emergence of norms in simulated networks of linguistic influence. *University of Pennsylvania Working Papers in Linguistics*, v. 15, n. 2, p. 81-90, 2010.

FRAN, R. M.; GONTIER, N. On constructing a research model for historical cognitive linguistics (HCL): some theoretical considerations. In: WINTERS, M. E. et al. (eds.). *Historical Cognitive Linguistics*. Berlin: Walter de Gruyter, 2010. p. 31-69.

HEYLIGHEN, F. The science of self-organization and adaptivity. In: *Encyclopedia of Life Support Systems*. v. 5. Paris: EOLSS Publishers, 2001. p. 253-280.

_____. Complexity and Self-Organization. In: BATES, M. et al. (eds.). *Encyclopedia of Library and Information Sciences*. New York: Taylor & Francis, 2009. p. 1215-1224.

JAKOBSON, R. *On language*. Cambridge: Harvard, 1990. 560 p.

KELLER, R. *On Language Change:* The Invisible Hand in Language. London: Routledge, 1994. 196 p.

KÖHLER, R.; ALTMANN, G. Aims and methods of quantitative linguistics. In: ALTMANN, G. et al. (eds.). *Problems of Quantitative linguistics*. Černivci: Ruta, 2005. p. 12-41.

KÖHLER, R. Synergetic linguistics. In: KÖHLER, R. et al. (eds.). *Quantitative Linguistik/Quantitative linguistics*: ein internationales Handbuch/an international handbook. Berlin: Walter de Gruyter, 2005. p. 760-774.

KRETZSCHMAR, W. A. *The Linguistics of Speech*. Cambridge: Cambridge University, 2009. 296 p.

_____. *Language and Complex Systems*. Cambridge: Cambridge University, 2015. 242 p.

LABOV, W. *Principles of Linguistic Change*. v. 2. Social Factors. Oxford: Blackwell, 2001. 592 p.

LARSEN-FREEMAN, D.; CAMERON, L. *Complex Systems and Applied Linguistics*. Oxford: Oxford University, 2008. 287 p.

MAC WHINNEY, B.; O'GRADY, W. (eds.). *The Handbook of Language Emergence*. Oxford: Wiley-Blackwell, 2015. 656 p.

MINNETT, J. W.; WANG, W. S. Modelling endangered languages: the effects of bilingualism and social structure, *Lingua*, v. 118, n. 1, p. 19-45, 2008.

MUFWENE, S. *The Ecology of Language Evolution*. Cambridge: Cambridge University, 2001. 276 p.

MÜHLENBERND, R.; QUINLEY, J. Signaling and simulations in sociolinguistics. *University of Pennsylvania Working Papers in Linguistics*, v. 19, n. 1, p. 129-138, 2013.

NARANAN, S.; BALASUBRAHMANYAN, V. Power laws in statistics and related systems. In: KÖHLER, R. et al. (eds.). *Quantitative Linguistik/Quantitative linguistics*: ein internationales Handbuch/an international handbook. Berlin: Walter de Gruyter, 2005. p. 716-738.

RACZASZEK-LEONARDI, J. Multiple systems and multiple time scales of language dynamics: coping with complexity. *Cybernetics and Human Knowing*, v. 21, n. 1-2, p. 37-52, 2014.

SAMPSON, G.; GIL, D.; TRUDGILL, P. (eds.). *Language Complexity as an Evolving Variable*. Oxford: Oxford University, 2009. 336 p.

SAUSSURE, F. *Course in General Linguistics*. Chicago: Open Court, 1986. 236 p.

WEDEL, A. Self-organization in phonology. In: VAN OOSTENDORP, M. et al. (eds.). *The Blackwell Companion to Phonology:* Suprasegmental and Prosodic Phonology. Oxford: Wiley-Blackwell, 2011. p. 130-147.

WILDGEN, W.; BRANDT, P. (eds.). *Semiosis and Catastrophes:* René Thom's Semiotic Heritage. Bern: Peter Lang, 2010. 185 p.

ZUIDEMA, W.; DE BOER, B. Modelling in the language sciences. In: PODESVA, R. et al. (eds.). *Research Methods in Linguistics*. Cambridge: Cambridge University, 2013. p. 422-439.

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