Chapter 1
Complexity in Language: A Multifaceted Phenomenon

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1. COMPLEXITY in Linguistics

1.1. Linguistics and the science of complexity

COMPLEXITY has attracted a great deal of attention in linguistics since about 2001, at a rate that proportionally far exceeds its invocations in the field since Ferdinand de Saussure, the father of our discipline, in the early 20th century. The number of books bearing *complexity* in their title is remarkable, suggesting that there may be an emergent research area whose focus is COMPLEXITY in Language. The dominant question that the relevant linguists have addressed is the following: To what extent does complexity as observed in different languages or in different modules of the language architecture display both cross-systemic variation and universal principles? This has entailed asking whether there are languages that are more complex than others and explaining the nature of differences.

One is struck by the sheer number of book-length publications alone,[1] and even more when the numerous journal articles and chapters in edited volumes are added to the total count, regardless of whether or not they include *complex(ity)* in their title. On the other hand, one is also shocked by the scarcity of works that explain what COMPLEXITY is, apparently

[1] Book titles containing the term *language* or *linguistic(s)* include: Dahl (2004), Hawkins (2005), Risager (2006), Larsen-Freeman (2008), Miestamo *et al.* (eds., 2008), Sampson *et al.* (eds., 2009), Givón (2009), Givón & Shibatani, (eds., 2009), Pellegrino et al. (eds., 2009), Aboh & Smith (eds., 2009), Faraclas & Klein (eds. 2009), Cyran (2010), Trudgill (2011), Robinson (2011), McWhorter (2012), Kortmann & Szmrecsanyi (eds., 2012), Housen & Kuiken (2012), Blommaert (2013), Culicover (2013), Massip-Bonet & Bastardas-Boada (eds., 2012), Newmeyer & Preston (eds., 2014), Berlage (2014), Kretzchmar (2015), and Baerman, Brown & Corbett (2015).

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because it is assumed to be known[2]. This is quite at variance with publications outside linguistics, which are devoted to explaining various ways in which the notion can be interpreted. The subject matter has actually also evolved into what is identified by some as "complexity theory" or the "science of complexity" (see some citations below).

Thus, a convenient starting point for this chapter and the book it introduces is to explain what is meant by *complexity*, as it applies both to linguistics and other research areas. Etymologically, the term *complexity*, as a nominalization from *complex*, can ultimately be traced to Latin *complexus*, a past participle of the deponent verb *complecti* 'embrace, comprise', according to *Webster's Collegiate Dictionary*, and also confirmed by the *French Petit Robert*, which translates it as *contenir* 'contain'. According to the *Online Etymology Dictionary*, the adjective *complex* 'composed of parts' was borrowed from French *complexe* 'complicated, complex, intricate' (17c.), from Latin *complexus* 'surrounding, encompassing', past participle of *complecti* 'to encircle, embrace'. In transferred use, the verb meant 'to hold fast, master, comprehend', from *com-* 'with' and *plectere* 'to weave, braid, twine, entwine'. The noun *complex* evolved to mean 'a whole comprised of parts'.

This etymological definition remains very generic. Beyond it, it appears that no strong consensus has emerged in the science of complexity itself about what *complexity* means (see, e.g., Strogatz 2003; Gershenson, ed. 2008; and Mitchell 2009). There are nonetheless some common themes and properties that recur in the relevant literature. They include the following, which overlap in some ways:

[2] A noteworthy exception is Ellis & Larsen-Freeman's (2009) "*Language as a complex adaptive system*", which is derived from the lead and seminal chapter by Beckner et al. (also identified as "The Five Graces Group"), "Language is a complex adaptive system: A position paper."

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1) Complexity arises from the coexistence of components that interact with each other, not necessarily from the fact that a space or a system is populated with several components or members; it is therefore interactional.
2) Complexity arises from the dynamics of activity coordination or synchronization that integrate individuals as members of a population (e.g., ant colonies, bird flocks, and fish schools); thus, it is dynamical.
3) Complexity emerges from non-linear evolution, which is driven by multiple factors whose significance may vary at different stages of the evolutionary process; its effects are not constant, subject to the changing values of the relevant variables.
4) Complexity lies in what brings order out of chaos[3], through what is also known as "self-organization" and was formerly referred to as an "invisible hand" (Smith, 1776).[4]
5) There is complexity in any system where the properties of the whole do not amount to the sum of the properties of the components.
6) Finally, complexity is the peculiarity of emergent patterns in a system in constant state of flux between disorder and transient order (or equilibrium). In other words, complexity arises from the dynamics of coexistence and interaction and/or cooperation of components toward generating the properties of whole.

As we are reminded by Loureiro-Porto & San Miguel (this volume), *complex* should not be confused with *complicated* (*pace* the etymology of *complex(ity)* cited above). For instance, airplanes are complicated rather than complex pieces of engineering. Despite the

[3] "Chaos" is used here as in "chaos theory," which studies systems whose behavior is highly sensitive to initial conditions, in the sense that small differences in initial conditions may produce quite divergent evolutions or outcomes. It also seeks to capture emergent patterns from the interplay between order and disorder, from which complexity arises.

[4] For a more linguistic take on the "invisible hand", see (Keller 1994).

very large number of parts, each part has a clear function which makes it possible—and to some extent easier—to predict its contribution to the whole. On the contrary, it is not evident which role each component of a true complex system, such as an ant colony or a flock of flying birds, plays in the behavior or function of the whole system, or what it specifically contributes as a unit to the larger, integrated whole.

Connecting the above interpretations to Language, the idea that a system consists of interacting components is not new. It was indeed at the core of the structuralist program, in which phonemes, words, and other linguistic units were primarily considered as components of structures. An important peculiarity of this tradition is that a language was typically construed as an autonomous system, independent of its speakers and the wider ecology in which it and the speakers evolved. Thus, internal forces and their interactions were paid much more attention than external ones. While this suits the etymology of the term *complexity* and some of the points above, it understandably omits other interpretations made evident in the science of complexity, especially regarding the dynamical aspects. Complexity arises not just from how the different parts interact with each other but also from how they respond to external pressures of the environment, or the external ecology (Mufwene 2001), outside the system.

However, decades later, despite the increasingly interdisciplinary nature of the relevant scholarship in other research areas, most linguists deal with complexity almost as if hypotheses in those other areas couldn't possibly apply to languages. This observation does not include modelers, often coming from the field of artificial intelligence, who have invoked multi-agent systems or network theory to investigate language emergence and change, for instance, de Boer & Zuidema (2010), Ke *et al.* (2008), Kirby (2000), and Steels 1998, 2011a). Aside from them, others such as Massip-Bonet & Bastardas-Boadas, ed. (2012) or

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Kretzschmar (2015) have also highlighted the dynamic aspects of language behavior. Overall, linguists still have to ask themselves what interpretation of LANGUAGE they subscribe to, what COMPLEXITY may mean under that particular interpretation, whether the architecture of Language and linguistic behavior are exceptional in relation to the common properties of complexity that have been observed in other aspects of nature, and/or how they contribute to this expanding, more inclusive research endeavor.

1.2. Components, structures, and domains in linguistic complexity

Likely because most of them have ignored work in the science of complexity, linguists have remained faithful to the interpretation of a COMPLEX SYSTEM as 'a whole consisting of several parts'. Thus, the more parts the whole consists of, the more complex it is assumed to be, regardless of how the parts interact with each other. This explains why an approach commonly found in the literature consists in counting the number of elements of a linguistic system in order to evaluate its complexity. Depending on the specific study, the focus may be the number of phonemes, morphemes, or words, but also relations among variants of such units (allophones, allomorphs, or near-synonyms), or yet the number of categories, rules, or constraints that can be posited in a system. This has come to be called "bit complexity" and has been criticized as uninformative (DeGraff 2001, 2009).

Indeed, this approach does not pay attention to possible relationships between the components, and goes counter to the well-known idea that "simply more does not mean more complex." For example, a set of five bodies moving purely randomly, in the absence of any interaction force, is not as complex as, let alone more than, a set of five bodies, or even three or four, moving according to gravitational forces they exert on each other (Pointcaré 1891)..

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The possibility that a whole with fewer parts engaged is several multilateral interactions can generate more interactive complexity cannot be accounted for in a bit-complexity approach, for instance when an item generates different interpretations depending on what other item it combines with. This may be illustrated with the particle *up* in combinations with various verbs such as in *pick up, give up, show up,* and *look up*. While the item *up* is, for all intents and purposes, the same particle in all these constructions, its contribution to the meaning of each phrase appears to vary. This variation suggests that the particular dynamics of each combination produce the meaning of the whole phrase. The overall meaning of each phrase is not the sum of the meanings of its parts. (See, for instance, Victorri 1994 on the dynamics of such constructions.)

To be sure, some linguists have shifted from counting elements to assessing how they make a system together. These linguists have first attempted to identify the patterns of interactions between the components and then infer linguistic complexity from the interactions. Their approach has involved building mathematical graphs and then quantifying their "structural complexity" with an appropriate measure. The vertices of the graph correspond to the components of the system, while the edges connecting them reflect how they can be related meaningfully. Another strategy is presented in Coupé *et al.* (this volume), in which patterns of co-occurrences of phonetic segments are evaluated with respect to the individual occurrences of these segments, in order to detect significant interactions.

Rather than focusing on (mostly pairwise) interactions between elements, another systemic view seeks to describe the linguistic system in terms of regularities and irregularities. A classical concept is here *Kolmogorov complexity*, which is the length of the shortest program which can produce the description of the system (given a programming

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language). Behind it is the central idea that the more compressible a piece of information is, the lower its complexity is too. This algorithmic approach to complexity (Dahl 2004: 42) is more processual than the previous one, since the algorithm has to be run in order to get the description. While it has been proved that the Kolmogorov complexity cannot be computed, reasonable approximations can be obtained with standard compression algorithms and be applied to compare complexity between objects. The size of an archive containing the compressed version of the initial description of the system and the means to decompress it (i.e. a self-extracting archive) is inversely proportional to the complexity of the system. Rissanen's (1978) "minimum description length" is another possible approximation to Kolmogorov complexity.

Such approaches have been applied especially to measuring the complexity of morphological systems (e.g. Bane 2008, Walther & Sagot 2011). Some linguists have also echoed Gell-Mann's (2003) concern that Kolmogorov complexity is highest in the case of totally random expressions, while we intuitively do not see totally unordered systems as complex. His counter-proposal for measuring complexity effectively, named *effective complexity*, is the length of the shortest description of the set of regularities of the system. Along these lines, Newmeyer & Preston (2004:182) also state that "the more patterns a linguistic entity contains, the longer its description, and then the greater its complexity".

Although these quantitative approaches offer more refined considerations of linguistic complexity, they rely on the descriptions that linguists can provide of a linguistic system. When different options compete in this regard, the quantification methodologies themselves do not help. This echoes Edmonds' (1999) statement that complexity lies before all in the eye of the interpreter of the system. Another way of considering this is that a descriptive account of complexity can be at odds with a more functional approach: does the

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complexity of the description of an utterance always correspond to the amount of difficulty the hearer experiences in processing it? Does the description capture adequately the nature of the neural and psychological encoding, and its consequences in terms of processing? Is such an approach to complexity informative about the overall complexity of a language?

Attempts to assess the complexity of a whole language present an additional difficulty with the same endeavor in other, physical or cultural systems. For example, ferromagnetic materials, a well-known physical system in which self-organization of microscopic magnets can occur in the absence of strong external magnetic field, are only composed of identical elements without hierarchical structure. By contrast, in the case of languages, different modules and levels of analysis – phonology, morphology, syntax, semantics etc. – can be distinguished, and the hierarchical integration of their elements (starting from meaningless sound units) into phrases, sentences, and discourse raises a number of issues. Complexity can be investigated in each module independently but also between these modules, raising research questions such as whether the lesser complexity of a module will be balanced by the greater complexity of another.

Such a conception of EQUILIBRIUM can also be considered within a domain, if, for example, one attempts to check whether the greater complexity of the consonant or vowel system is counterbalanced by the lesser complexity of the syllabic structures (Maddieson, 2011). Technically, comparing distinct domains such as phonology and morphosyntax is uneasy beyond simply counting elements, which, as remarked above, typically disregards the interactions between them.

On a more theoretical level, what is obviously missing from the relevant literature is the interactional complexity that arises from the division of labor and cooperation between different components, including members of the same module, though it is not evident how

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many modules must ultimately be posited to account for how the production and interpretation of utterances work in a language. As a matter of fact, Lieberman (2012) goes as far as rejecting the idea of modules, arguing that the neurons of the brain are connected in a way similar to (though more complicated than) the parts of an automobile engine. However, if one subscribes to the modular architecture of language, it becomes important to understand how the modules interface with each other during the production and interpretation of utterances, certainly not in a linear way (McCawley 1998). According to the latter, the modules work concurrently, rather than sequentially, as is made evident by, for instance, the correction of false starts in production and self-corrections of the interpretations of utterances as the discourse evolves.

Let's assume that the materials of a language fall in one or another module (viz., phonology, morphology, syntax, etc.), each of which makes a clear contribution to the overall system, while its components (such as individual sounds in a phonemic system) do not. We may then have to wonder whether languages do not fall in between complicated and complex systems, consistent with Loureiro-Porto and San Miguel's distinction (this volume). The question is difficult to answer within the bit-complexity approach.

On the other hand, determining whether a language is complex or complicated becomes rather pointless without reference to something that it can be compared with. This explains why linguistic complexity has typically conjured up cross-linguistic research. Any measure of complexity presupposes or entails some cross-linguistic comparison of phonological inventories, morphological systems, etc., as is evident, for instance, in discussions about whether or not creoles' grammars are simpler than those of other languages (e.g., McWhorter 2001, DeGraff 2001). This approach also suggests that a language may exist that has no, or very little, complexity built in it. However, from the point

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of view of the interaction of modules, McWhorter's (2001) and Gil's (2001, 2009) claims about the simplicity of the grammars of, respectively, creole vernaculars and Riau, Indonesia, beg the question. However, see Gil's (2009) reaction below.

1.3. From static to dynamic linguistic systems

The complexity of a linguistic system can be assessed synchronically, relative to a given time, typically the present, regardless of what the system was like before. However, languages are constantly changing and adapting to satisfy various communication pressures, including those that index speakers and the circumstances of their interactions. Beyond structures that may be assumed to be a static response to a fragile assemblage of structural constraints—in the spirit of a saying usually attributed to Ferdinand de Saussure: "la langue est un système où tout se tient"—linguistic systems are in a constant state of flux, with new components appearing and older ones evolving or disappearing. It thus makes sense to ask how complexity evolves under these ecological pressures, and see languages or their subsystems as *complex dynamical systems* (Bruckner *et al.* 2009).

Self-organization and *emergence* express how order and regularities arise from an initially disorganized state. They are fundamental processes in the study of physical and biological complex systems, for instance, how ants may build optimal paths between their nest and a food source, how microscopic dipoles can align to create magnetic domains, and how traders' activity at a market can result in macroscopic events such as economic bubbles or crashes. These concepts can be invoked to account for linguistic phenomena such as the emergence of new language varieties. For example, both SELF-ORGANIZATION and EMERGENCE can be invoked to explain how elements from several languages have been selected, in varying proportions, into a new variety, called creole. Linguistic systems can merge – with

some features being selected and possibly modified, and others rejected – into what appears to be a new dynamic equilibrium.

Unlike in the science of complexity, linguistics stands out also by the limited attention that has been given to how complexity emerges, i.e., from a diachronic perspective, relative to language development and to the phylogenetic emergence of language. Exceptions include Wang *et al.* (2004), Givón (2009), Lee *et al* (2009), Mufwene (2012), and some of the authors contributing to this volume, especially Bart de Boer, Tom Schoenemann, and Luc Steels, the first and the last based on modeling the emergence of language. It is to this fold of linguistic complexity that they were invited to contribute.

Different time scales relate to different evolutionary processes: from the ontogeny of complexity in child language acquisition, to its modifications in language change and the evolution of languages, to its rise during the phylogenetic emergence of Language. In ontogenetic and phylogenetic evolution, the focus is especially on how a system develops/evolves from architecturally poorer to richer structures (see, e.g., Dahl 2004, Givón 2009, Givón & Shibatani, eds. 2009). Regarding historical language changes, phenomena such as grammaticalization can be studied with a focus on whether they increase or decrease the complexity of the system (e.g. Heine & Kuteva 2007). Other attempts yet derive diachronic models from synchronic constraints, and observe how system coherence and complexity evolve between lower and upper bounds (Coupé *et al.* 2009). From a phylogenetic point of view, one should not dodge the question of how complexity arose during the transitions from vocalizations to naming and the rise of phonetic systems, to predication and the emergence of simple sentences, all the way to modern linguistic systems (e.g., Mufwene 2013).

The linguistics discourse has generally overlooked the dynamics of the linguistic elements in relation to each other, such as what may happen when a new sound is added to the phonetic inventory of a language; or when a preposition is used as the syntactic head of the predicate phrase (like in *dis buk fuh you* 'this book [is] for you' in Gullah), whereas a verb has traditionally been required in this position in English (Mufwene 1996). That is, while speakers/signers modify the extant system with their innovations, the latter may trigger other adjustments in the system. This is the case in the sentence *You bin fuh come* 'you had/were expected to come' in Gullah, where, because it can function as head of a predicate phrase, the preposition *fuh* has also been coopted as a marker of OBLIGATION, the counterpart of a modal verb in English. (As head of the predicate phrase it can also be modified by the anterior tense marker *bin*, regardless of whether it functions as a preposition or as a modal marker.) Such a change by cooption of extant materials is undoubtedly true of other cultural systems, which are also adaptive but depend primarily on the activities that shape them, those of the practitioners of the culture. Future research should return to this issue, which arises also from some of the contributions to the present book.

An important question in such systemic adaptations is: What are the forces or constraints responsible for linguistic change? Answering this question offers complementary and enriching perspectives on linguistic complexity. Indeed, the previous approaches can all fit a framework where linguistic structures are considered in isolation and studied on the basis of their internal (possibly dynamic) patterns of occurrences or interactions. But considering the various dimensions—social, cognitive and pragmatic—of what may be called the *ecology of language* (Mufwene 2001, 2008; Coupé 2016) opens further avenues toward a more complete understanding of linguistic complexity.

1.4. Complexity and language ecology

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Language ecology has usually been invoked in relation to social factors (Mufwene 2001, Lupyan & Dale 2010).[5] Indeed, a language does not exist outside its social environment; it is a communal creation, with structures shaped through speakers' communicative acts. It displays emergent patterns, which linguists have attempted to capture in the form of rules and constraints, from a synchronic perspective. However, there are ecological factors that arise from within the system itself that also influence the evolution of a language, e.g., frequency, transparency, regularity, and length of particular variants. They determine which variants will prevail and which ones will remain minority alternatives or will be given up.[6] Innovations and their replications (or copies) compete among themselves, subject to these and other ecological factors, social and otherwise (Mufwene 2001, 2008, Blythe & Croft 2009). This is especially noticeable in cases of language contact, when a new variety (such as a creole) emerges and retains only a subset of the variants in the prevailing language (called *lexifier*) and only some of the competing substrate features are selected into the emergent language variety.

Equally, if not more, interesting are cases where the competition[7] is not resolved. For instance, in (standard) English, the primary stress in the word *exquisite* may be place on the

[5] Mufwene actually applies the term *ecology* to a wider range of factors, both internal and external to particular languages, some direct and others indirect, that influence the evolution of a language, including its vitality. He applies the term to any factor that may be considered as (part of the) environment relative to a language (variety) or a linguistic feature being discussed. Relative to language evolution, some ecological factors are economic and historical. Relative to the phylogenetic emergence of Language, Mufwene (2013) singles out the human anatomy and the brain/mind as critical ecological factors.

[6] Linguists such as Weinreich *et al*. (1968), McMahon (1994), and Labov (2001) have invoked ACTUATION (similar to but not exactly the same as ACTUATOR in physics) in reference to the particular combination of factors, which are indeed ecological, that produce particular changes at specific places and at specific points in time. This tradition of course underscores the need to approach language evolution from the point of view of complexity and emergence, as these notions are construed in the science of complexity, in dynamical terms.

[7] As explained in Mufwene (2008), "competition" is used here in the same sense as in *evolutionary biology*, applying to variants, organisms, or species that ecology may not sustain equally, favoring one or some but disadvantaging the other(s). In languages, variants for the same function (including languages spoken in the same community) are often rated differently by their speakers or signers, a state of affairs that explains why

first or second syllable; a relative clause may start with a null complementizer, with the complementizer *that*, or with a relative pronoun (a *wh* form); and some speakers say *I want you not to come*, whereas others prefer *I want you to not come*. There are indeed a host of similar examples not only in English but in other languages too. What also appears evident in such cases is not only the number of distinctions that are made but also the ways in which the distribution of the competing expressions are articulated. No assessment of complexity in a language should ignore this interactive aspect of the system, which is consistent with Saussure's notion of OPPOSITION between forms or between constructions: the expressions derive their meanings from how they are opposed to, i.e., distinguished from each other.

How is variation managed in a language or speech community? Can it remain free, in the sense that a speaker/signer may use any variant or another without any communicative or social consequences? Or is it constrained by other factors that are social, such as age, gender, ethnicity, profession, and level of education, or those that stem from the precise context of interaction? Are the constraints rigid or flexible? The interfacing of systems (consisting of structural units and rules) and social constraints emanating from the communities using and shaping the languages appear to foster alternative interpretations of linguistic complexity, which also explains variation in the way that linguists discuss it, as is evident in, for instance, Sampson *et al*. (eds., 2009) and Massip-Bonet & Bastardas-Boada (eds., 2012). To the extent that languages can be constructed as communal systems, complexity arises at least as much from the dynamics of interaction within the population associated with the language, as from the actual system hypothesized by the linguist (or any analyst). Linguistic complexity therefore conjures up complexity of linguistic structures and

some disappear. From an evolutionary perspective, and even that of language ontogenetic development (influenced by who the learner interacts with), different speakers/signers may not rate the variants in identical ways.

external constraints exercised by social factors, including specific kinds of social interactions and the particular business or social networks in which one operates.

No speaker/signer has complete knowledge of their communal language as an ensemble of idiolects (Mufwene 2001), while they all use it and adapt their respective idiolects relative to other users. The speakers'/signers' mutual accommodations and their respective responses to novel communicative pressures (which are similar to adaptive responses of elements of better understood complex adaptive systems) drive change or evolution. This peculiarity explains the claim that languages as both practices and systems are in a constant state of flux, hardly staying in equilibrium, and are therefore emergent phenomena.

These dynamic aspects of complexity are hardly quantifiable. They also make it obvious that, as stated by Beckner *et al*. (2009), the agents of the emergence of complexity are the speakers/signers who manipulate the system. They are the ones that modify it, innovate new forms and structures, introduce new dynamics of interaction among the different components of the system on different levels, and therefore modify the patterns of complexity in one way or another. On the other hand, this agency also sets the discourse on linguistic complexity at odds with epistemological models of complex systems in the science of complexity, such as ant colonies and flock of flying birds, in which the agents are parts of the system rather than its users/manipulators.

Speakers and signers largely differ from birds flying in flocks or ants living in colonies in that they do not reposition themselves physically but modify their idiolectal characteristics to approximate those of the other speakers or signers they wish to align with socially or professionally. In other words, a bird situates itself as part of a system, whereas a speaker or signer realigns their linguistic productions and uses these modifications to situate

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themselves socially or professionally but not in the linguistic system itself. Also, while a bird never changes the innate rules that dictate how, while flying, it adapts its speed and direction to the speeds and directions of neighboring birds (see, e.g., Hildenbrandt *et al.* 2010), humans are much more flexible when it comes to adapting their behaviors—i.e. linguistic strategies—which are not what they are as individuals.

At the root of this behavioral flexibility obviously lie highly developed cognitive capacities, which allow us to interiorize part of the complexity of the linguistic system we are immersed into. Crucially, they enable us as speakers to anticipate the possible effects of our words on the hearer's mind, and to reconstruct as hearers what was in the speaker's mind when they produced the message we just received.

Beyond social aspects, cognitive aspects also shed light on linguistic complexity. As much as languages are social, communal constructions, they are also processed and stored in individual minds. In a way similar to the aforementioned algorithmic complexity, linguistic complexity can be estimated based on the cognitive efforts required by the mind (conceived of as the state of the brain in activity) to produce or process a message. The question of how difficult specific items or subsystems are to learn especially points to a *learnability complexity*.

Along these lines, Dahl (2009) makes a distinction between, on the one hand, "absolute complexity," ascribed to the mechanics of the system, and, on the other, "relative complexity," based on how much difficulty a learner experiences in learning a language. What does this "relative complexity" tell us about the inherent complexity to learn a given language? The answer appears to be negative, because "relative complexity" is predicated on the fact that speakers of particular languages find some other languages harder to learn for various reasons, for instance, the tone contrasts are too difficult to replicate faithfully, or

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there are too many morphological distinctions (especially inflections) to remember accurately, or there are too many constraints regulating when particular variants can or should not be used.

This complexity must be assessed variably, depending on which speaker of which language is learning which other language. However, all languages are effectively learned and spoken by their speakers, regardless of their very different strategies when it comes to conveying information. There is no evidence that it takes speakers of, say, tonal and agglutinating languages longer to develop native competence in them than speakers of toneless and English-like languages that are not agglutinating nor polysynthetic.

What is generally overlooked in this respect is also inter-individual variation in learning skills, even in the acquisition of one's mother tongue. For instance, while the English article system (including usage of bare nouns in the singular form) and distinction between the preterit and present perfect seem too illusive to many non-native speakers, there are also many others who have no serious problem with them.

Going further, we must also consider the fact that, beyond moderate inter-individual differences, all living humans are endowed, through their common biological phylogeny, with the capacity to learn modern language(s), identified by Noam Chomsky as the "biological endowment for language." Assuming that this capacity is unique to the human mind, the cognitive aspects of linguistic complexity are relevant when it comes to the phylogenetic evolution of human societies and communication. For instance, Mufwene (2013) argues that, as the hominine mental capacity increased and hominines developed larger social organizations in which they had to manage their modes of coexistence and norms of interactions, the pressure for more informative communicative systems grew.

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According to MacNeilage (1998), neurobiological changes and displacements of communicative functions in the brain supported these changes.

Mufwene (2013) also assumes that languages as communicative technology developed incrementally without foresight of the emergent structures, with every speaker and signer contributing in different ways to the process (some more successfully than others), exapting the current system not necessarily according to the same principles. Thus, languages appear to have evolved "chaotically" (i.e., without a masterplan, according to the science of complexity) toward more complexity both in the architecture and size of the system and in the quantity of interactions between components within and between their different modules.[8] The modules themselves may have instantiated complexity, in that they may be assumed to have emerged by self-organization, with the mind dividing the labor to be run concurrently, for faster production and processing of utterances (Mufwene 2012, 2013).

A last overarching ecological factor bearing on linguistic complexity is the pressure to communicate adequately or accurately. Most of the contributions to Ellis & Larsen-Freeman (2009, best articulated by *Beckner et al*.) and to Massip-Bonet & Bastardas-Boada (2012) stand out in subscribing to the idea that languages adapt to the communicative needs of their speakers/signers, thus they reflect changes in the latter's cognition and adaptations to their social and other ecologies. They keep changing over time, also reflecting the accommodations that the speakers/signers make to each other toward the emergence of

[8] This is not a denial of regularities within the different modules of languages. Exaptations are based on analogies between, on the one hand, the new meanings to be conveyed or the new function to be played and, on the other, some meanings or functions currently in use, except that different speakers/signers do not necessarily perceive the same ones when they innovate. Thus, although they introduce variants that compete with each other, they also introduce regularities (Mufwene 2008). Because the resolution of competitions between variants depends of various factors that are not so predictable, the situation is comparable to chaos in complexity.

some communal norms (however transient these may be), including how they respond selectively to each other's innovations (see also Mufwene 2001).

Along this line, some usage- and agent-based investigations in artificial intelligence attempt to shed light on the emergence of complexity in linguistic systems. They focus on how individual communicators (often identified by modelers as "agents") exapt current structures for novel communicative needs and generate new structures (e.g., Lee *et al*. 2009). However, very little of this (e.g., Wang *et al*. 2004) is integrated in ways that also address the role of ecological factors identifiable in the anatomical, mental, and social aspects of communication (as discussed above) that contribute to the emergence of various interpretations of linguistic complexity.

Different individuals may have (noticeably) different communicative needs. How exaptations are made depends on the context of use of the extant communication system and on individual speakers'/signers' skills, based on their ontogenetic trajectories. But the evolution of languages by exaptation applies to both the phylogenetic and the ontogenetic development of linguistic systems. We assume that our hominine ancestors, say one million years ago, needed less expressive communication systems, owing to their less developed cognitive/mental capacities and less complex social organizations. Similarly, young infants have fewer communicative needs than adults, and they make fewer nuances, especially regarding the pragmatics of utterances. Their cognitive capacities and social skills are definitely less developed in the sense that they have not yet developed a full "theory of mind" or mind-reading capacity, which forms the basis of the inferential adult communication (Sperber & Wilson 2002). They do not do as well as adults regarding, for instance, metaphors, irony, implicatures, and the significance of connotations (in addition to

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denotations) in linguistic communication. Their range of skills for mature competence are not fully in place by puberty and will certainly continue to expand until adult life.

Hawkins (2009) introduces the concept of EFFECTIVE COMPLEXITY[9], according to which an utterance with more words may be easier or faster to process than an alternative with fewer words. This appear to be puzzling, as the longer an utterance is, the more taxing it is on the short-term memory for processing, in part because the number of (morpho-)syntactic relations within the utterance increases. Or, to repeat our quotation from Newmeyer & Preston (2004:182) above, "the more patterns a linguistic entity contains, the longer its description, and then the greater its complexity". However, according to Hawkins (2009: 259), "complexity in form processing is matched by simplicity with respect to the processing functions performed by rich case marking and definite articles." That is, what is structurally more complex is not necessarily more complicated. The position suggests that we should not overlook the computational aspect of processing utterances, as one may have to infer more when less is said explicitly, such as in the case of the so-called "restricted code." However, Gil (2009: 24) denies that there is evidence of such "hidden complexity" in Riau, Indonesia, which, he claims, has very little syntax.

Koster (2009) and Mufwene (2013) see "language[s] as technology" developed to meet humans' communicative needs. However, as there are alternative ways of solving the same problems, different populations have not developed their languages in identical ways, which account for typological variation. As with other technologies, it is indeed legitimate to ask whether some languages are simpler than others. However, as observed by Hawkins (2009), among others, what must one measure in assessing complexity: only the physical, mechanical parts of the language technologies or also their abstract aspects involving

[9] Not to be confused with Gell-Mann's "effective complexity" introduced in the beginning of this chapter.

various structural and pragmatic rules/principles? The particular way in which one answers this question should help determine whether comparing different languages relative to their complexity, as opposed to trying to understand how complexity arises in language and how to explain it, is an intellectually rewarding exercise.

Moving closer to practitioners of the science of complexity (viz., outside linguistics), how variably does complexity arise from the different ways in which different populations shape their languages through their communicative acts? From an evolutionary perspective, languages are perceived not as designed deliberately by particular populations and in different ways, but rather as arising spontaneously from attempts by different populations to communicate using phonetic and/or manual means (Mufwene 2013). This piecemeal emergence and evolution, in unpredictable, "chaotic" ways, favor treating them as complex adaptive systems. This is also the kind of position that arises from proponents of usage-based or construction grammar, including Croft (2000, 2001, 2009), Steels (2011b, 2012), and Kretzschmar (2015), among others. From this perspective, students of linguistic complexity must explain the consequences of thinking of languages as complex adaptive systems. For instance, is the addition of a phoneme to the phonemic inventory of a language, or the deletion of one from it, as adaptive as the addition a new meaning or word to the lexicon of a language, or even the loss of one meaning or word? Are the systemic consequences the same in both cases? What about grammatical rules?

Overall, the various folds of linguistic systems call for an approach to the global complexity of languages that is distinct from assessing the complexity of particular linguistic structures. That is, the matching of linguistic structures with their ecologies – i.e. the social, cognitive and interactional contexts in which speakers evolve – may justify positing a *usage complexity*, rooted in the actual use of language rather than in more theoretical structural

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considerations. A linguistic system that fully responds with its structures to the communicative needs and the context of use may be seen of little complexity, while a complex linguistic system may be characterized by structures that do not reflect these needs. For example, in different languages of the North Pacific Rim, dominant winds play a significant role in the linguistic description of space and spatial directions (Fortescue 2011).[10] An adequate coupling exists between these linguistic systems expressing space and their context of use, which can relate to a low complexity. But due to climatic change in these regions, wind patterns have recently been changing (Gearheard et al. 2010) and some linguistic systems may therefore now be at odds with their context of use. In such cases, the coupling is now characterized by a greater complexity, and change is needed to restore a better adequacy of the linguistic system, e.g. move away from winds to describe directions. Such a complexity seems to echo a cognitive complexity, in the sense that non-adapted forms, given their discrepancy with the actual physical and mental world of the individual, may require more cognitive efforts to be processed or learned.

Since speakers' natural and socioeconomic ecologies constantly change, as do their communication needs, a language always has to adapt to these changes. This coupling, which is typically unplanned and *ad hoc*, cannot be perfect, partly because of the time needed for the linguistic system to adapt to new social and pragmatic evolutions (and possibly cognitive evolutions in a phylogenetic perspective); additionally, the coupling is imperfect because speakers/signers have no foresight of the ultimate consequences of their current communicative behaviors for the overall system of their language.[11]

[10] Expressing directions according to winds can also be found in other languages, for example in the Oceanic family (Palmer 2007).

[11] As made evident by the literature on child language development and on the phylogenetic emergence of language, the changes affecting speakers/signers have to do with the increase of their mental capacity and the

1.5. The debate over the equal complexity of languages

A classic issue in linguistics pervades the various approaches to linguistic complexity discussed in the previous sections: it is the question whether one (type of) language is more complex than another (Sampson 2009, Gil 2009, Trudgill 2009). Some of the recent publications have specifically been driven by McWhorter's (2001) claim that "The world's simplest grammars are creole grammars." The debate is most evident in Sampson *et al*. (eds., 2009), in which the contributors articulate different views.

As is made more obvious by especially Bisang (2009) and Deutcher (2009), most, if not all, claims that one (type of) language is more, or less, complex than another depend on what modules of a language are considered as (most) representative of the architecture of language and sufficient to justify one's conclusion that a (type of) language is more complex than another: morphology and syntax only or also the phonology and semantics? For the proponents of equal complexity, an argument is that compensations may take place between these modules: if morphosyntax is more complex in language A than in language B, semantics in B will be less complex than in A. However, this literature has typically focused on "bit complexity" (i.e., a system having more units than another), which again does not do justice to the interactions between components.

If one considers the issue more globally, what does one make of the pragmatic considerations that help us decide whether, say, *drop the ball* must be interpreted literally or as an idiom? Does a language boil down to the mechanics that help us code and decode information (Hawkins 2009)? Or does it also include the principles that guide the encoding

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richer experiences they develop with their social and other aspects of their ecologies, including the climates of their settings, the fauna, and the vegetation. If coordinating their social lives is the primary function of language (Croft, this volume), then all these factors exert constant pressure on language to keep adapting to new communication needs, which Mufwene (2013) characterizes as adaptive responses to changing ecological pressures.

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and decoding processes, including the choices that one must make among competing variants and the extent to which one must rely on context during these processes? Both Bisang (2009) and Deutcher (2009) conclude that there is no well-articulated measure of what the global complexity of a language is; therefore claims that some languages are more, or less, complex than others amount to what Deutcher compares to "urban legends."

This is not to say that the relevant literature has not taught us anything about complexity. Some studies shed light on interesting ways in which some languages vary in the mechanics of their forms and constructions, regardless of whether or not these are considered as compensations: for example, languages that are spoken at a faster syllabic rate—e.g. Spanish and Japanese compared to Mandarin and English—tend to need more syllables to convey a given semantic content, and vice-versa (Pellegrino *et al.* 2011). Introducing speech rate—and thus language usage—in the equation, this study enabled the authors to shift the debate from over a putative (un)equal complexity of languages to over whether languages have an equal communicative capacity.

If languages are complex adaptive systems relative to the communication needs of their practitioners (according to Mufwene 2013, in ways similar to technologies with varying designs and developed incrementally to solve similar problems), what is to be gained from comparing, for instance, the overall complexity of a pidgin to that of a non-pidgin? After all, they are not used in the same ecologies of interactions nor have they evolved to meet identical communication needs: one is used strictly as a lingua franca for limited communication needs (typically basic informal trade transactions), whereas the other is used as a vernacular for a broader range of communicative functions. Is the structure of a pidgin less modular? Aren't pidgins modular and generative like other languages? Don't utterances in a pidgin involve compositionality and therefore some form of syntax, although this may

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not be as elaborate as in non-pidgin languages? Haven't pidgins emerged in a non-linear fashion? Don't they respond to novel communicative pressures in the same way as non-pidgin languages? Besides, Gil (2001, 2009), for instance, argues that limited syntax is not an exclusive peculiarity of pidgins. We must ask whether traditional discussions do not simply suggest that there are alternative ways of developing or evolving a language relative to the communication needs it is intended to satisfy.

In other words, while it is indeed legitimate to question the assumption that all languages are equally complex, it is not clear that most of the current scholarship can help linguists answer questions such as the following: Why are human languages (including incipient pidgins and child language) more complex than animal means of communication, and in what specific ways? How do human languages as emergent phenomena or complex adaptive systems vary among themselves from the point of view of complexity? Aside from the obvious fact that they differ typologically in various ways, do they display different patterns of complexity? In terms of the complexity of the overall linguistic system, are there informative ways of articulating why a language may be claimed to be more complex than another and how? Do these challenges call for an operational definition of Language, which can be assumed by all who engage in measuring the overall complexity in particular languages or some of their modules?

2. The 2011 workshop on language complexity

The following short history will help the reader put the contributions to this book in the relevant perspective. The book evolved out of a successful workshop also titled *Complexity in language: Developmental and Evolutionary perspectives* that we the editors, along with Jean-Marie Hombert and Egidio Marsico hosted at the Collegium de Lyon in May 2011, when the lead editor was a fellow there. We had invited a select slate of experts in evolutionary

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linguistics and child language development, in paleontology, and in artificial intelligence to assess the state of art, focusing on ontogeny and phylogeny, without necessarily overlooking synchrony. The invitation stated the following goals:

> For the "Complexity" workshop, our aim is to sort out things about the most useful way(s) to conceive of complexity in language. Need there be only one way or can there be several ways specific to particular research objectives? For instance, should the interpretation in relation to the phylogenetic emergence of language be the same as in comparisons of structures of modern languages? Indeed, can one claim that one language is more complex than another? If the answer is affirmative, how does he/she go about demonstrating it? If the answer is negative, what are the arguments in support of the position? Does the scholarship on language complexity measure up to the current scholarship on complexity theory? Can one discuss complexity without discussing emergence as understood in complexity theory? We would like to address some of these questions and/or any others that you may think of.

To be sure, some authors such as Östen Dahl and Talmy Givón discuss some of these aspects of complexity briefly, the former especially in relation to emergentism and the latter in relation to the phylogenetic evolution of language. Nonetheless, we think that modern linguistics may benefit from more exchanges of ideas, especially those also engaging colleagues from other disciplines who are modeling various dynamical (systemic and social) aspects of language. We want to emphasize that our goal is not to downplay the relevance of those approaches that focus on different aspects of structural complexity. Rather, it is to shed more light on the other, interactional/dynamical and emergentist aspects of complexity that deserve just as much attention and provide us a better sense of how linguistic communicative systems differ from their nonlinguistic counterparts both systemically and socially.

The contributors to this book address COMPLEXITY from the perspectives of both the evolution and the ontogenetic development of language. They focus on social dynamics involving decisions that speakers or signers make (not necessarily consciously) during their

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interactions with others and on the dynamics that produce systems out of the different units or constructions they use frequently in their utterances. This approach helps us address the question of whether, say, pidgins (leaving creoles alone) still exhibit some complexity and remain generative, in the sense that they can generate new structures and thus be adapted to the expanding communication needs of their speakers, as is evidenced by expanded pidgins such as Cameroon and Nigerian Pidgin Englishes, Tok Pisin, and Bislama.

3. The chapters

The body of the book starts with the chapter by Luc Steels and Katrien Beuls. Focusing on the origins and evolution of grammatical agreement as a case study, they use multi-agent modeling to explore how various aspects of complexity (especially in the system and in forms, among others) emerge in language. Their working assumption is that complexity arises gradually from innovations produced by interactants largely to meet their new communication needs. It arises also from the competing variants (phonetic, lexical, syntactic, and semantic) they introduce during the process, owing largely to imperfect copying. On the other hand, this communal form of complexity decreases as the speakers' emergent idiolects convergence toward some norm (which maintains less variation), the outcome of their repeated successful interactions. According to Mufwene (2001), mutual accommodations that speakers/signers make to each other are indeed among the mechanisms that drive selection in language evolution, in particular the emergence of new language varieties such as creoles.

Steels and Beuls illustrate another fold of complexity by discussing, with some examples, the way in which ambiguity (in simpler forms or structures) increases complexity in processing. This arises from the fact that the hearer has to eliminate references that may be associated with particular constructions and/or interdependences between constituents

that are not relevant in a multi-word utterance. They show what a critical role agreement markers play in disambiguating utterances. This suggests that, although they have typically been interpreted as adding complexity to the structure of a language, agreement markers actually decrease complexity in processing. If complexity is assessed in terms of processing time (Newmeyer & Preston 2014), morphological complexity does not appear to be particularly costly when it enables speakers to express more information compacted in a short form, as with fusional markers such the Latin *–arum* inflected on a noun to indicate that it is PLURAL, FEMININE, and in the GENITIVE/POSSESSIVE. This appears to corroborate Hawkins' (2009: 259) position that "complexity in form processing is matched by simplicity with respect to the processing functions performed by rich case marking and definite articles."

Likewise, the cooption of some current forms for new grammatical functions, such as in grammaticalization, is said to be a case of "damping complexity," as the strategy reduces guess work in figuring out the new meaning or function. So is the erosion of forms or constructions that follows for ease of production, supporting their hypothesis that speakers tolerate just the necessary amount of complexity they need to communicate efficiently in their language; otherwise they dampen it. Steels and Beuls' discussion highlights the fact that the architecture of a language is multi-modular (though it is not evident how many modules one must posit) and that complexity can be assessed differently, depending of the work that the module is assumed to do. Though we need not subscribe to the traditional position that all languages are of equal level of complexity, we may need a multi-dimensional metric for assessing the extent to which a language is more, or less, complex than another.

Chapter 3 focuses on the following question: When a language can function with just a dozen contrasting sounds (e.g., Hawaian), why does the average phonetic inventory of the

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world's languages amount to 29 sounds? This leads Bart de Boer to start with the observation that "Languages are more complex than is strictly necessary for their communicative function." Assuming that this makes it possible to tell which language is more complex than another phonetically, he focuses on determining "which aspects of linguistic complexity are due to cultural processes, and which aspects are due to cognitive biases."

One may want to entertain the question of whether the emergence of languages can really be attributed to cultural processes? If culture is understood roughly as the particular ways in which members of a particular population behave and do things, is this question well-formulated? Is a linguistic system not a cultural system enabled by the particular evolutionary trajectory of its practitioners and shapers? Not only is cultural evolution not mutually exclusive with biological evolution, it also presupposes it. Only animals endowed with uniquely generative and highly adaptive mental/cognitive capacities (viz., the hominine species) have produced human cultures, aspects of which include culture-specific languages (Mufwene, in press).

We want to clarify that De Boer does not want to exclude the role of biological evolution in language evolution cum cultural evolution. What he means by "cultural processes" appear to be related to the fact that nobody really builds a language with foresight and based on a masterplan. If we can borrow from William Croft (this volume), a linguistic system emerges in the same way as other "emergent phenomena" (the way systems are seen in the science of complexity), through the addition and/or disuse of the strategies that the interactants develop in the here and now of their communicative acts, as they integrate gradually into a system. De Boer concludes tentatively that the "complexity of phonological systems is due to cognitive mechanisms that re-use and generalize building

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blocks." This appears to be the consequence of transmission through learning by inference, which replicates unfaithfully and introduces (more) variation, as well as of the nonlinear way in which linguistic systems evolve.

In Chapter 4, Thomas Schoenemann argues, in ways consistent with Bart de Boer, that "the complexity of language is the result of the evolution of complexity in brain circuits underlying our conceptual awareness." According to him, modern languages have evolved from the complex interactions of biological evolution, cultural evolution, and successions of ontogenetic development in several generations of individuals in particular populations. Linguistic systems, with their patterns, have been facilitated by humans' "socially-interactive existence," which is reminiscent of Steels and Beuls' discussion of how communal norms emerge. From this perspective, Schoenemann argues that language complexity can best be understood when it is grounded in an evolutionary perspective, focused on interactions of the biological evolution with the changes in the ecologies in which the interacting agents evolve.

Highlighting differences and similarities between humans and chimpanzees in particular, notably in the ways they conceptualize about the world, Schoenemann also concludes that the differences can be correlated with differences in the anatomies of their brains. However, some of the similarities also suggest that humans' ability to conceptualize is pre-linguistic, suggesting that the emergence of Language and the complexification of its architecture are the consequence of the further complexification of the human mind, beyond the chimpanzee under the conditions of "social-interaction existence." He observes that ontogenetically "the development of expressive grammatical complexity appears to be an exponential function of the size of the lexicon."

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Assuming that phylogenetic language evolution proceeded gradually, William Croft argues in Chapter 5 that "at least some elements of the structural complexity of modern human languages are the consequence of the cognitive complexity of the conceptual structures being communicated." He also argues that "It is only in its social interactional context that the evolution of linguistic complexity can be understood," thus, that "the evolution of social-cognitive complexity (in terms of joint action) is a prerequisite for the evolution of structural complexity of linguistic signals." Language as a communal phenomenon is the product of joint action; it is more than the sum of the actions and systems of its practitioners. Thus it satisfies the characterization of a complex system according to practitioners of the science of complexity, especially since it can work only if every member of the community cooperates towards its successful behavior/practice.

From an ecological perspective (Mufwene 2001, 2013), Croft also highlights the role played by the material in determining the shape of the emergent semasiographic system ("encod[ing] information in a lasting, visual medium"), for instance, the role of clay in reducing the number of iconic signs. If this hypothesis is correct, one may assume that the shapes of the Chinese logographic characters were largely influenced by the use of papyrus and ink. Overall, Croft's general observation is that writing systems, which have evolved from simpler non-linguistic and more iconic semasiographic conventions, emerged gradually, becoming more arbitrary as they were increasingly being used to represent speech. It is, of course, debatable whether the Chinese system has evolved to serve speech, as the same graphic representation can be read equally in any Chinese variety (e.g., Mandarin or Cantonese).

Croft also argues that "Writing did not express grammatical elements until centuries after its first emergence. In other words, substantial common ground between author and

reader was required to interpret just the linguistic form encoded by early writing." Illustrating how exaptation works in cultural evolution, Croft shows through his discussion of musical notations how elements of the current system are recruited for new functions, to help expand it (to the satisfaction of the performers/practitioners). This is indeed reminiscent of the exaptation that takes place during grammaticalization.

Based on how semasiographic systems have evolved, gradually and from restricted to a wider range of functions, Croft hypothesizes that "language began in highly restricted functional domains, and its extension to become a general-purpose communication system was a long and gradual process in human prehistory." He further concludes that, like the semasiographic systems, "language initially functioned simply as a coordination device for joint action," conveying minimal information.[12] It is only later that it became more explicit, conveying richer information, and developed more complexity in its architecture, especially as it developed "displacement" (Hockett 1959), the capacity to convey information about entities and states of affairs that are not present.

In Chapter 6, Christophe Coupé, Egidio Marsico, and François Pellegrino start with a historical synopsis of the interest of linguists in complexity since Ferdinand de Sausure's (1916) characterization of a language as a system consisting of interacting parts. Then they consider the particular ways in which scholarship in complexity theory, as practiced in especially physics, mathematics, and cybernetics, has inspired some of the current research in phonology. They also underscore the fact that "A language is an aggregate of individual idiolects" (comparable to Mufwene's 2001 idea that it is "extrapolation from idiolects"). As spoken of in linguistics, individual languages are reductions of convenience, which overlook

[12] Croft uses *coordination* in a way related to *cooperation* in theories of human and cultural evolution, in reference to members of a population engaging in joint actions.

inter-idiolectal variation, which is more closely matched by Michel Breal's (1897) idea that every idiolect is somewhat a separate language. Both inter-idiolectal variation and the breakdown of sounds into (articulatory and acoustic) features add complexity in the ways phonological systems can be thought of.

Coupé, Marsico, and Pellegrino also highlight the difference between acknowledging that a system is complex and assessing the extent or level of complexity, while citing some studies that have proposed particular metrics. They warn against importing uncritically hypotheses developed by physicists and mathematicians, which are typically based on simplified models of reality, although they are useful research tools. This is consistent with their basic position that any research field (including linguistics) can contribute to the science of complexity.

Applying the statistical method to 451 phonetic inventories, the authors address the question of whether phonological systems world-wide present evidence of preferred interactions among segments that may be based on manner or point of articulation, nasality and orality for vowels, or any other phonetic features. That is, are there any particular features that are more significant than others in the emergence of phonological systems? Their conclusions include the observation that, from an evolutionary perspective, "it [is] (…) difficult to conclude in favor of strongly non-linear interactions between either features or segments." They also note that it is difficult to assess the overall complexity of a language using tools developed for physics and biology, as they do not transfer faithfully to language. While it is evident that traditional, typologically-oriented discussions of linguistic complexity do not capture the full picture, linguists should consider a more informative metric for addressing the question of whether or not different languages display the same level of global complexity.

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Barbara Davis focuses, in Chapter 7, on the ontogenetic development of the phonological component of language to explore the kind of light the analysis may shed on the phylogenetic evolution of language. Like Schoenemann, she grounds her discussion in the interpretation of COMPLEXITY in the science of complexity. According to her, "Within the tenets of complexity science, phonological knowledge and behavioral patterns can be seen as emerging from connections enabled by *general-purpose* child capacities such as learning and cognition as opposed to language-dedicated modular mechanisms." The emergence of a complex phonological system in the child is driven by both their cognitive-neural capacities and the production system capacities which work in cooperation. She refers to the complex interaction between the environment and the child's brain in the gradual emergence of his phonological system, which appears to call for an approach similar to the analysis of emergent phenomena in the science of complexity, which may presuppose only the disposition of a mind sensitive to complex interactions and ready for complex systems rather than specifically for language.

Davis' observations are similar to those of Schoenemann. She terms this approach "biological-functional approach to phonological acquisition," according to which "outcomes of phonological acquisition result from multiple interactions between heterogeneous aspects of a complex system." She moves on to explain the significance of change in both the ontogenetic development and the phylogenetic emergence and evolution of language, especially in introducing complexity throughout the adaptations that the emergent system undergoes to satisfy current communicative pressures. The ACQUISITION of phonology is thus characterized as "'change' in infant output capacities." Thus, the "progressive diversification in the inventory of sound types and how they are produced in sequences relative to ambient

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language patterns is usually considered a critical index of increasing complexity toward mature phonological capacities."

In Chapter 8, Lucía Loureiro-Porto and Maxi San Miguel approach complexity in language practice from the point of view of language choice in a multilingual setting, especially those that may result in language loss. That is, they focus on complexity that arises not from interactions between the different components and/or modules of language as a system but from various factors external to the system that influence speakers' choices in their discourses, especially when they have to alternate between languages in a bilingual setting. Their study involves modeling as a simplified tool for addressing certain specific questions regarding linguistic behavior in this particular case.

From the outset, the authors articulate a distinction they make between a COMPLEX SYSTEM from a COMPLICATED SYSTEM (such as an airplane), which is "composed of many parts, each [of which] has a clear, identifiable function which makes prediction possible." Complexity has to do largely with the unpredictability of the properties of the whole from those of the parts. From the point of view of language practice, the whole regards the vitality of a language, as it depends on language choices speakers make when they interact with each other, without foresight of the ultimate consequences of these decisions regarding the languages in competition. It is the whole ecosystem in which the language belongs, in coexistence with other languages, that is of concern. What are the factors that individually or in combinations determine the choice of one or another language (variety) on specific occasions of social interactions? Things are made more unpredictable by the fact that speakers are not necessarily coordinated about their decisions in the typically dyadic or triadic interactions they are most often engaged in.

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Loureiro-Porto and San Miguel's modeling reveals the significance of local interactions in bilingual settings, regarding how they reduce the chances of sustaining the vitality of both of the languages in competition. Other interesting questions arise too, as language evolution is not uniform from one bilingual setting to another. One of them regards when multilingualism spells the endangerment of the less prestigious language(s) and when it does not. In the real world, the explanation can be found in differences between the population structures of the multilingual settings: for instance, those fostering assimilation also favor endangerment, whereas those that are socially segregated according to language groups do not.

Because it simplifies reality, of necessity, modeling helps us become more aware of the complexity of factors that influence the linguistic behavior of (members of) a population and thus bear on language vitality. Underscoring the complexity of actuating factors is the fact that even those population structures that are assimilationist do not endanger the disadvantageous languages at the same speed either. Loureiro-Porto and San Miguel's modeling reveals differences between small-world networks, regular lattices, and networks with community structure. As the authors conclude, "the kind of network in which interactions take place is a strong influencing factor on language dynamics, as it plays a central role in the potential survival or disappearance of one of the languages in competition."

Closing the book, Albert Bastardas-Boada approaches linguistic complexity both from the parts to the whole and from the whole to the parts. The aspect of complexity he focuses on is that which arises from the interaction of the system with its ecology, including the socio-conceptual matrix of the speakers' interactions, economic pressures, the distribution of political power, and the effects and language policies. Complexity increases as a

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consequence of the fact that populations are not uniform and foster variation, which obtains not only inter-individually and between groups, but also inter-generationally. According to the author, a language must be conceived of "as a historical and, therefore, temporal phenomenon, with earlier events playing a major role in how the phenomenon evolves." History shapes and may provide some explanation for the present, including current linguistic behavior.

There are indeed other aspects of complexity that this book, like the dominant literature in linguistics, still does not tackle, despite our focus on developmental and evolutionary perspectives. One of these is the extent to which increase in population size affects complexity in the communal language, perhaps more in the pragmatic and social aspects of its usage than in its structures. Another is whether contact with (an)other language(s) reduces or increases structural complexity, and under what specific conditions. Is contact the only explanation for why major world languages such as Modern English and Modern French have lost most of the inflections of Old English and Old French, respectively? On the other hand, hasn't contact also increased complexity in their systems in other ways, such as in introducing alternative grammatical rules and/or changing some of the rules while preserving some exceptions? These are all interesting topics for future studies.

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