

Chapter 2

Complex Adaptive Systems: The Case of Language

Abstract This chapter outlines current perspectives on language conceived of as a ‘Complex Adaptive System’. A complex system is composed of diverse and autonomous parts that are interrelated and interdependent. With a view to circumscribing research on grammar under the scope of Complexity Theories, the notion of system is introduced along with core concepts in Ecological Linguistics, such as dynamic systems, emergentism and affordance, interacting agents and environment, adaptation and variation. Systems thinking has been a central issue in many diverse disciplines since Whitehead’s Process Philosophy. A general science of organized complexity turned into a robust General Systems Theory thanks to Von Bertalanffy, Weiss, Boulding and Prigogine who, among others, offered detailed studies on emergentism in both the natural and the social sciences. In the 1980s the Santa Fe Institute, New Mexico, elaborated a theoretical framework for complex systems that represents a solid basis for an entirely new approach to the study of organizational behaviours between the entities constituting different types of systems. Complexity research shed new light onto the study of language as a Complex Adaptive System that links the two realms of nature and culture. Language is a system composed of many speaking agents that linguistically interact in their speech communities and overtime their communicative interactions produce emergent changes at many different levels of the linguistic system. As it happens in the natural world where small organisms reorganise themselves into more complex systems, a form of ‘emergentism’ occurs in grammar, which is not an inventory of steady rules, but an ever-changing by-product of communication, whereby systematic linguistic patterns are the outcome of a process of ‘sedimentation’ of frequently used forms. Language is thus always provisional, subject to negotiation and change, an open-ended set of forms that actual use constantly restructures and resemanticizes, and it is therefore constantly far from completeness and stabilization.

Keywords Systems thinking • Interacting agents • Emergentism • Patterns of language usage • Grammar

2.1 Complex Systems

In general terms, a ‘complex system’ is any system consisting of a large number of heterogeneous entities that, interacting with each other and with their environment, generate multiple layers of collective structure exhibiting hierarchical self-organization without centralized control. The aggregate activity of the entities undergoes processes of non-linear change, that is, changes that often give rise to emergent features that cannot be derived from the summations of the interactive behaviour of the entities, nor predicted beforehand on the basis of assumable causes, nor described through one level only of explanation. The origin of ‘Systems thinking’ can be traced back to the mid-twenties of the last century when Alfred North Whitehead argued that reality is not composed of substances only, but also and principally of events and their interrelations; from this assumption he developed his ‘process philosophy’ or ‘philosophy of organism’ (1929).

Process Philosophy claims that reality is a state of being that occurs in time and is endowed with dynamic features. It rejects Western metaphysics, which described reality as if it were composed of static individuals and the state of being as conceptually ‘simple’, internally unchangeable and undifferentiated; in line with the ancient postulate dating back to Parmenides who saw the state of being as a ‘*what-is*’ state, Western metaphysics thought of reality as composed of primary static units, called ‘substances’, which remain exactly the same at any instant in time; in other words, reality, or existence, was seen as timeless and unchanging. Against this eternalist view, Heraclitus himself had already maintained that everything was nothing else than a ubiquitous and continuous flux, and advanced the idea of the world being composed of organizational units and ruled by dynamicity, in its two forms of dynamic transition and dynamic permanence. It is this latter conception that Whitehead endorsed when he turned from mathematics to philosophy. He propounded the idea that reality is composed of continuously changing entities, modes of becoming and types of occurrences; the world was conceived of as an assembly of processes—organic, physical, cognitive, and social—that interact at and across layers of dynamic organization. This is tantamount to saying that reality undergoes continuous changes but holds temporally recurrent and stable aspects of persistence, which are the outcome of dynamic organization following from the constant interaction of processes. Reality is hence comparable to a network of interrelated processes, with human being representing essential parts of such a network to the extent that all their actions and behaviours affect the surrounding world. In the words of Whitehead (1925),

the misconception which has haunted philosophic literature throughout the centuries is the notion of ‘independent existence’. There is no such mode of existence; every entity is to be understood in terms of the way it is interwoven with the rest of the universe.

Whitehead rejected the traditional notion of time-invariant substance because it denies any type of experiential grounding, which is the fundamental mode through which we experience ourselves as well as the world around us. Furthermore, recent

developments in physics, such as the relativity theory and the quantum theory that proved the dematerialization of physical matter, convinced Whitehead that the order of the universe represented an old-fashioned viewpoint that was no longer suitable to account for the spontaneous effects of many scientific phenomena, i.e., effects emerging without any clear correlation to observable causes. The traditional cause-effect relationship was deemed insufficient to explain the intricate multi-faceted world we live in, and it could be no longer assumed that every observed effect stems from an observable cause, or that the analysis of past events could predict future events. The notion of causality, that is, the ability to identify whether one event causes another, dates back to philosophers such as Kant and Hume, who believed that humans make an attribution of causation when they have certain types of perceptual experience (e.g., when A is perceived to precede B in time, B is always perceived to be preceded by A, and so on, then A is perceived to ‘cause’ B). As a matter of fact, there are many cases in which the effects we observe and the causes we want to identify are not obviously related. Aspects of many different phenomena across various disciplines are quite regularly unpredictable and new methods of analysis are necessary in order to identify the reasons of such unpredictability. The first example of an indirect effect that is usually mentioned in this respect refers to the 19th century Austrian School of Economics, which observed and described how, in market systems, order was not necessarily planned but appeared to be spontaneous, or ‘emergent’, that is, not entirely related to assumed causes. A simpler example of emergence we can find in biology where proteins merge to form cells, which in turn merge to form organs, organisms, species and ecologies. One further example is provided by ecology, the ecosystem, its changes and the (human) actions that may cause unpredictable changes.

More or less in the same years when Whitehead demonstrated that entities in the world interconnect in many complex ways thus giving rise to spontaneous, emergent outputs and outcomes, the biologist Ludwig Von Bertalanffy approached the study of a general science of organized complexity: he delivered his seminal lecture at the University of Chicago in 1937 and his ideas were first collected in his paper *Zur einer allgemeine Systemlehre* (1945), then in the volume *General Systems Theory* (1968), where he lay the foundations of the new theory of systems. Von Bertalanffy felt the need to advance the concept of ‘open system’ since he found that Sadi Carnot’s closed system of thermodynamics, which appeared reminiscent of Newton’s scientific laws, was insufficient and inadequate to describe the large amount of biological phenomena involving living entities, which necessarily need to exchange not only energy, as in the case of thermodynamics, but also substances for their functioning and survival. He introduced a fresh approach that viewed the world not as ‘chaos’ but as ‘organization’:

The 19th and first half of the 20th century conceived of the *world as chaos*. Chaos was the oft-quoted blind play of atoms, which, in mechanistic and positivistic philosophy, appeared to represent ultimate reality, with life as an accidental product of physical processes, and mind as an epi-phenomenon. It was chaos when, in the current theory of evolution, the living world appeared as a product of chance, the outcome of random mutations and survival in the mill of natural selection. In the same sense, human personality, in the

theories of behaviorism as well as of psychoanalysis, was considered a chance product of nature and nurture, of a mixture of genes and an accidental sequence of events from early childhood to maturity. Now we are looking for another basic outlook on the world - *the world as organization*. Such a conception - if it can be substantiated - would indeed change the basic categories upon which scientific thought rests, and profoundly influence practical attitudes. This trend is marked by the emergence of a bundle of new disciplines such as cybernetics, information theory, general system theory, theories of games, of decisions, of queuing and others; in practical applications, systems analysis, systems engineering, operations research, etc. They are different in basic assumptions, mathematical techniques and aims, and they are often unsatisfactory and sometimes contradictory. They agree, however, in being concerned, in one way or another, with 'systems', 'wholes' or 'organizations'; and in their totality, they herald a new approach. (1968, pp. 166-167)

The phenomenon of emergence was therefore believed to be an integral feature of evolution and the introduction of the theory of evolutionary change brought with itself the scientific notions of 'self-organization', 'chaos', and 'complexity', which could elucidate the reasons why dynamic organizations exert causal constraints. The 'Cartesian reductionism' could explain only those simple mechanisms where a machine could be studied by reducing it to its distinct parts without losing its machine-like character, and then by analysing those parts in a context formulated according to dynamics. Yet, nature cannot be explained through the limits of the Cartesian machine metaphor; its complexity, in fact, gives rise to unpredictable patterns of emergence. A number of natural phenomena, in particular evolution and developmental biology, show that a system is characterized by its ability to change extensively and to generate novel structures and properties out of the existing ones. A new perspective was therefore necessary if one wanted to explain how factors such as dynamicity, emergence and self-organization play a central role in nature. Whitehead and, after him, process philosophers substituted the Parmenidian '*what-is*' perspective with one that focused upon the central role of '*what-is-occurring*' as well as of '*ways-of-occurring*'. The new research paradigm of philosophical inquiry foregrounded the dynamic sense of being and the on-going process of becoming, or occurrence, together with the different types of dynamic entities and their relationships. It is not our task in these pages to go into detail about the various types and modes of occurrences that process philosophers proposed so as to develop a taxonomy of dynamic beings; suffice it here to say that some of the processes they investigated correspond to our common idea of a process; in this respect, processes are temporally developments analyzable as temporally structured sequences of steps of an occurrence where—and this is what is of main importance in our discussion—each step is qualitatively and numerically different from any other. Given the fact that the whole world is a process between entities that continuously interplay and interrelate, reality is a complex system that encompasses the processual aspects of nature, action, and cognition.

Von Bertalanffy's transdisciplinary approach of Systems Theory proposed that phenomena cannot be understood by simplistically breaking down the whole into its components, but they must be studied holistically along with the environment they belong to. Systems Theory offers a range of unifying principles that can be applied to a wide array of disciplines, thus enhancing a process of integration

between the natural and the human sciences. Some of the principal aims of Systems Theory are the ensuing ones (Von Bertalanffy 1968, p. 38):

1. There is a general tendency toward integration in the various sciences, natural and social.
2. Such integration seems to be centered in a general theory of systems.
3. Such theory may be an important means for aiming at exact theory in the nonphysical fields of science.
4. Developing unifying principles running ‘vertically’ through the universe of the individual sciences, this theory brings us nearer the goal of the unity of science.
5. This can lead to a much-needed integration in scientific education.

The ideas elaborated by Whitehead and Von Bertalanffy along with those of other scholars like Weiss, Boulding, and Gerard respectively in biology, social sciences and physiology, gave rise to ‘Systems Thinking’, the new theoretical framework that would influence much of the academic community in the second half of the 20th century. An example is provided by Nobel Prize Ilya Prigogine who, in the sixties, studied the self-organization of systems and observed how the interaction between molecules and energy gave rise to systems able to unpredictably organize themselves into a number of emergent complex structures:

the security of stable, permanent rules are gone forever. We are living in a dangerous and uncertain world that inspires no blind confidence. Our hope arises from the knowledge that even small fluctuations may grow and change the overall structure. (1984, p. 313)

However, it is right and proper to remind that it was John Stuart Mill (1843) who first introduced the concept of emergentism. Mill advanced the idea that a system’s properties are much more than the mere sum of its component, an idea further developed by Gestalts theorists in the field of psychology:

The chemical combination of two substances produces, as is well known, a third substance with properties different from those of either of the two substances separately, or both of them taken together. Not a trace of the properties of hydrogen or oxygen is observable in those of their compound, water. (1843/1930, p. 243)

Bates et al. (1998) offered a description of emergentism in nature that illustrates the indirect relationship between cause and effect with great clarity:

the hexagonal shape of the cells in a beehive does not follow from the properties of the wax, of honey, or the geometric preferences of individual bees. Rather, hexagons arise from the practice of packing circles together in a way that minimizes wasted space. (1998, p. 590)

Honeybees deposit ball-rounded drops of wax-coated honey into the hive, and drops squeeze together giving rise to an emergent hexagonal shape out of a process of optimizing space.

If we now turn our attention to what happens in the system of language, we can observe that words, idioms, formulae and constructions are the outcome of emergentism: the adverb ‘*perhaps*’ has ‘emerged’ out of the frequent usage of the longer expression: ‘*per chance it happens that*’. The same can be said of syntax: for example, the means sense of the *way*-construction as in ‘*Joe bought his way into the*

exclusive club’ has emerged from its central manner sense as in ‘*She elbowed her way through the crowd*’, which encompasses the idea of path creation and difficult motion that are not explicitly encoded in the utterance. What such examples have in common is that order is not pre-determined but spontaneous, emergent and in perpetual novelty.

It was exactly from the need to explain those phenomena that appear to be the outcome of pure randomness that in the 20th century Complexity Theories were elaborated (Kauffman 1995; Holland 1998; Lemke 2000), and many researchers set one of their main objects of study in the indirect, non-linear relationship between cause and effects. Since their inception, complexity theories have been applied, and further developed, in both the natural and the social sciences, as, for instance, biology, anthropology, psychology, cybernetics, and quantum physics. Complexity theories have brought to the forefront the inadequacy of the simplistic cause-effect relationship, have introduced the notion of ‘emergence’, and have made clear the fundamental issues of the non-linearity of systems, which is something that has overcome the linear and reductionist mode of thinking that had governed the scientific thought since Isaacs Newton’s times.

2.1.1 Complex Adaptive Systems

We have briefly sketched out in the previous section how Complexity Theories have enhanced a dialogue between the natural and the social sciences, thus fostering a profitable exchange of ideas and methodologies. The scientific exchange across a whole number of disciplines has resulted in an interactive forum among scholars who aimed to design methods for the description and analysis of complex systems and to identify those patterns and emergent behaviours common to different systems. With that goal in mind, in 1984 some members of the *Los Alamos Natural Laboratory* founded the *Santa Fe Institute*, New Mexico, thus gathering together researchers studying complexity from a wide range of disciplines. The new school of thinkers worked together in order to establish a common theoretical framework for complexity. The Santa Fe Group offered an insightful definition of complexity:

Complexity refers to the condition of the universe which is integrated and yet too rich and varied for us to understand in simple common mechanistic or linear ways. We can understand many parts of the universe in these ways but the larger and more intricately related phenomena can only be understood by principles and patterns - not in detail. Complexity deals with the nature of emergence, innovation, learning and adaptation. (Sherman and Schultz 1998, p. 63)

Over the years, systems complexity research has become known as the ‘Complex Adaptive Systems Approach’, or CAS for short. Complexity theories and CAS can thus be considered as two highly interrelated knowledge domains. The study of complex adaptive systems entails some main interconnected questions that are particularly useful in the context of language, since many of the possible

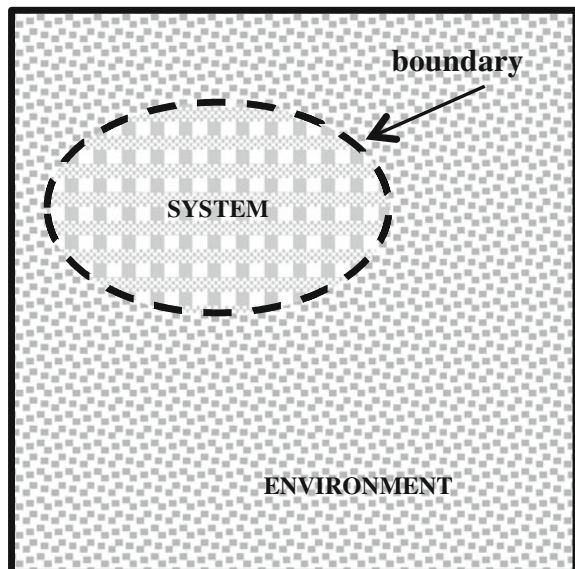
answers to those questions can be used to describe language as well as language learning:

1. how can complex systems be described? What are the parts composing them?
2. how do the different parts interact?
3. how does such interaction give rise to patterns of behaviour?
4. how do patterns of behaviour evolve and what consequences they trigger?

To provide detailed replies to the above questions, a working definition of system is necessary. Broadly speaking, a system is a set of entities, or *agents* as they are called, that interact together in such a way as to form a connected whole, with the whole being part of a larger environment. The system is discriminated as a part of the environment by establishing an imaginary boundary (Fig. 2.1).

The agents represent the system's structure and the behaviour resulting from their interactions influences the system's behaviour. One terminological clarification is here necessary: the term 'behaviour' is to be understood as the range of actions and processes carried out in response to a range of inputs—internal and external to the system's boundaries—in conjunction with the environment in which the system is embedded. Going into some detail, the organization of the system is maintained by a constant flow of energy; its behaviour is the outcome of the wide range of many different decisions made by individual agents, which choose about how to behave on the basis of information from the local environment they belong to. The agents behave in 'parallel processing', that is, they make their choices simultaneously with the result that they influence and boost or limit each other's behaviours. Behaviours are not random, but follow common rules: for example, agents in society behave according to decision-making rules (e.g., desires, interests,

Fig. 2.1 Simple representation of a system



or preferences), while agents in nature follow the rules of chemistry, gravity, or meteorology. From those rules emerges a novel global coherence, or dynamic stability, which is not the outcome of predetermined strategy or central control.

As we have hinted at above, systems are of different types. They can be closed or open, simple or complex, linear or non-linear. The systems that are central to our discussion about language and language learning, i.e., the ‘complex adaptive systems’, can be here briefly and provisionally defined as open, complex, and non-linear systems whereby speakers behave in such a way as to determine each other’s linguistic behaviours as well as the behaviour of the whole linguistic system. Before dealing with this topic in the next section, we will now illustrate the main features of different types of systems. We will then show that those features play a crucial function in the language system and in the language learning process as well.

First, systems can be closed or open. An open system is characterised by its steady exchange of substances and energy across its boundaries with the surrounding environment, and such an exchange is necessary in order to maintain its structure and functioning; all living systems are open systems. In contrast, in a closed system only energy is exchanged with the environment and the system maintains itself on its own resources (e.g., a pendulum or an electric circuit are examples of closed systems).

Second, systems can be simple or complex. Differently from the Newtonian paradigm, which centred upon the notion of linear dynamics, a system is defined complex when the whole holds a more complicated arrangement of its parts. Oppositely to a simple system, a complex system consists of many agents steadily and greatly interacting in unpredictable ways; the agents’ interactions influence the system and make it evolve over time without defined laws ruling its behaviour. One further specific feature that characterizes an open system is that it can be structurally divided into individual components, but it cannot be in any way functionally divided. A complex system is hence composed of parts whose synergistic functioning gives rise to the system itself, it cannot be reduced to parts, it is non-fragmentable. Therefore, in a complex system, functional components are not a mere collection of the parts, or agents, otherwise it could be fragmented and described by simple means of linear cause and effect relationships; functional components do stem from the system and their ontology does depend on the context of the system. Complex systems are open systems since most of them are nested within other systems to such an extent that boundaries may be difficult to trace. The spontaneous emergence of new forms of order in complex systems is called ‘self-organization’, which means that no external agent constructs and maintains the system, but the system emerges spontaneously from the internal interactions of its components. In self-organizing systems, the constant exchange of energy between agents maintains them far from a state of equilibrium, thus enhancing creativity and innovation.

Finally, systems can be linear or non-linear. A system is non-linear when the cause of its effects can be easily identified and the effects are always directly proportional to the cause. A non-linear system is an indivisible whole that exhibits emergent properties. In a non-linear system a cause can produce no effect at all, or a

tiny cause may produce even large effects. The indirectness of the cause-effect relationship is labelled ‘emergence’, that is, “the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems” (Goldstein 1999, p. 49).

Complex Adaptive Systems can at this point be defined as open, complex, and non-linear. To add some more flesh to the bone, they tend to accommodate along levels of integration; in other words, each system participates in a ‘stratified order’, that is, each system is part of and embedded within a wider whole, which in turn is part of and embedded within an even wider system, and so on so forth. At each level of the integration arrangement, each system is at the same time autonomous and integrated with the systems at its own level, at the lower level, and at the higher one. In the words of Frjtióf Capra,

the tendency of living systems to form multi-leveled structures whose levels differ in their complexity is all-pervasive throughout nature and has to be seen as a basic principle of self-organization. At each level of complexity we encounter systems that are integrated, self-organizing wholes consisting of smaller parts, and, at the same time, acting as parts or larger wholes. (1982, p. 280)

Since systems are multi-layered hierarchical organizations, agents at one level represent the building blocks for agents at the next level. As Holland says,

hierarchies are constructed on a ‘building block’ principle: subsystems at each level of the hierarchy are constructed by combination of small numbers of subsystems from the next lower level. Because even a small number of building blocks can be combined in a great variety of ways, there is a great space of subsystems to be tried, but the search is biased by the building blocks selected. At each level, there is a continued search for subsystems that will serve as suitable building blocks at the next level. (1998, p. 8)

With regards to the dynamic stability across layers, Young (1993) observes that complex, self-organising systems mediate interaction between the supra-systems they are a part of and the subsystems they are composed of:

there is a natural tendency for self-organized wholes to form. The wholes retain their identities, return to maximum stability after they have been disturbed, and to a certain degree regenerate their form when these have been fractured. (1993, p. 41)

In far-from-equilibrium systems, each agent’s process presupposes every other for its own occurrence; in the context of these particular process organizations, it is self-evident that the dependence amongst the single processes is not merely a matter of linear causation, but it is constrained by the simultaneous interactions of the entire system, ensuring that each process is functional for the occurrence of the system itself (Bickhard 2004).

From what has been outlined so far, we can pin down at least two main principles that appear to rule Complex Adaptive Systems: “order is emergent as opposed to predetermined, and the state of the system is irreversible and often unpredictable” (Dooley 1997). To sum up, a system, also labelled a natural system (Laszlo 1996), is composed of variables, constantly interacting with one another; each variable, or ensemble, “affects all the other variables contained in the system and thus also affects

itself” (Van Geert 1994, p. 50). In the words of Grobstein (1997), “the behavior of ensembles is both influenced by and influences the behavior of elements. There is a reciprocal causal relationship between parts and wholes”.

Variables, ensembles, or agents—in any way we decide to name them—adapt to their behaviours as well as to the environment in which they are embedded, while at the same time they self-organize and co-evolve without any centralized control (Kauffman 1995) producing emergent phenomena; these “are conceptualized as occurring on the macro level, in contrast to the micro-level components and processes out of which they arise” (Goldstein 1999, p. 49).

In addition, the complex system itself is a complex system, which draws energy from its environment in order to self-organize and reorganize; as an example, the weather system is composed of many different parts that interact and adapt to the environment. As a consequence of this perspective, scholars nowadays maintain that the wider the range of variables within the system, the stronger the system and the greater the number of possibilities enhanced to evolve along a constant reorganization so as to best fit with the whole environment.

We have explained in the previous pages, also with the help of a citation from Von Bertalanffy, that the world is not *chaos* but *organization*. Yet, the notion of *chaos* is crucial in Systems Thinking and, in their effort to understand how order emerges in non-linear systems, complexity theorists have argued that the agents within a system continuously interact so as to achieve a state of dynamic, far-from-equilibrium stability that they label ‘the edge of chaos’, whereby “chaos is a science of process rather than state, of becoming rather than being” (Gleick 1987, p. 5). Holland observes that in many scientific fields like economics, genetics, immunology, ecology, cognitive psychology, and artificial intelligence, there are

nonlinear systems that remain far from equilibrium throughout their history. In each case, the system can function (or continue to exist) only if it makes a continued adaptation to an environment that exhibits perpetual novelty. (1986, p. 8)

The edge of chaos, a feature that was first noticed at the end of the 19th century, became popular after a lecture delivered by Edward Lorenz, the founder of the Chaos Theory, who observed that, in weather forecasting, most atmospheric phenomena are non-linear, an idea that became famous also thanks to his most-quoted phrase: “One meteorologist remarked that if the theory were correct, one flap of a seagull’s wings could change the course of weather forever” (Lorenz 1963), an effect that he later rephrased as “one flap of a butterfly’s wings” and named ‘the butterfly effect’ (Lorenz 1969). In his insightful book entitled *Complexity*, Waldrop describes the edge of chaos as the balance point

where the components of a system never quite lock into place, and yet never quite dissolve into turbulence either [...] The edge of chaos is where life has enough stability to sustain itself and enough creativity to deserve the name of life. [...] the edge is constantly shifting the battle zone between stagnation and anarchy, the one place where a complex system can be spontaneous, adaptive and alive. (1992, p. 12)

The edge of chaos is hence the most productive state for a system because this is evidence of the highest degree of variety, that is, maximum activity and maximum

creativity. Given the fact that systems are not static and they constantly fluctuate from balance to chaos, a system has to constantly respond to the changes of the environment, otherwise it ceases to function as a system and therefore ceases to exist. Waldrop also observes that

frozen systems can always do better by loosening up a bit, and turbulent systems can always do better by getting themselves a little more organized. So if a system isn't on the edge of chaos already, you'd expect learning and evolution to push it in that direction [...] to make the edge of chaos stable, the natural place for complex, adaptive systems to be. (1992, p. 295)

George Lakoff (2011) has recently discussed indirect effects in complex systems and, commenting on the effects of hurricane Sandy, has coined the label “systemic causation”:

A systemic cause may be one of a number of multiple causes. It may require some special conditions. It may be indirect, working through a network of more direct causes. It may be probabilistic, occurring with a significantly high probability. It may require a feedback mechanism. In general, causation in ecosystems, biological systems, economic systems, and social systems tends not to be direct, but is no less causal. And because it is not direct causation, it requires all the greater attention if it is to be understood and its negative effects controlled. Above all, it requires a name: systemic causation.

From what has been observed so far, we can define three main types of behaviour that characterize systems: ordered, complex, and chaotic. Ordered systems show repetitive and predictable cycles of behaviour, while chaotic systems never achieve observable patterns. Complex systems fluctuate between areas of order, where stability enhances storage of information, and areas of chaos, where they can exchange communication. The edge of chaos represents the intermediate region between order and chaos where the opportunity for complex systems to process and exchange information is maximized: it is when they are on the edge that complex systems can learn from their own experience.

To draw all the lines together and conclude, complex adaptive systems are special types of open, complex, non-linear, dynamic, self-organizing systems that are able to maintain and process high levels of information; they constantly shift between order and anarchy at the edge of chaos, conserve sufficient structure to process information, while at the same time fluctuate in such a way as to create new information, i.e., new structures and patterns. In complexity theories the term ‘information’ is synonymous with the presence of distinguishable patterns and relationships. Complex Adaptive Systems are composed of many agents holding dynamic interactions in apparently random ways and affect one another as well as the whole system. Overtime the agents’ multiple interactions enable the whole system to go through spontaneous self-organization that leads to emergent patterned outputs. The interactions between agents are therefore more essential than the single agents themselves. Agents are unaware of the behaviour of the system as a whole and they react only to what is locally known or available. Since their interactions are non-linear, even small changes within a system can produce considerable effects and lead to large changes. Furthermore, with the system being part of a broader

environment, when the environment changes, the system itself adapts to the environment and, as a result of the changes of the system, the environment changes, thus triggering a constant cycle of changes. Complex adaptive systems adapt to the changes, evolve at each change, adapt to the new relationships in this way established with the environment, co-evolve along with the systems they interact with, learn from the process on the basis of previous experience, and predict similar changes to which they prepare accordingly.

2.2 Language as a Complex Adaptive System

The previous sections have illustrated how complex adaptive systems are interdisciplinary in nature as they can account for both the natural and the human sciences, and criteria such as emergence, adaptation and self-organization can be profitably applied for a detailed analysis of many diverse fields of knowledge. In the light of this, also language can be viewed as a complex adaptive system of interrelationships that speakers hold in their communicative environment through their linguistic actions. The advantage of assimilating language to complex adaptive systems enhances a description of the interconnections it holds with the cognitive and social environments in which it is embedded as well as an explanation of language variation at many different levels of its structural organization. To put it with Finke,

Language, traditionally often seen as part of culture and not of nature, is in fact a linking system between both realms. It preserves many natural features up to the present day that must be investigated by the methods of different natural sciences: its acoustic dimension, its physiological relations and its neurobiological base, for instance. But in other respects, it exhibits typical cultural achievements which must be considered in the light of typical methods of the cultural sciences and the humanities: its historical dimension, its interpretative openness, its aesthetic and poetic potentials, to mention just a few. (2008, p. 75)

We endorse Finke's view since we firmly believe that language is, as many researchers have demonstrated, the manifestation of both natural and cultural facts; it is therefore no longer tenable to state, as generativist linguists do, that language is an innate device capable of activating a set of pre-established grammatical rules in the speaker's mind, nor an once-for-all fixed, straitjacket structure. In their definition of language, Cook and Seidlhofer account for its multifaceted nature:

a genetic inheritance, a mathematical system, a social fact, the expression of individual identity, the expression of cultural identity, the outcome of a dialogic interaction, a social semiotic, the intuitions of native speakers, the sum of attested data, a collection of memorized chunks, a rule-governed discrete combinatory system, or electrical activation in a distributed network [...] Language can be all of these things at once. (1995, p. 4)

Language is the locus where many different components intertwine in dynamic and complex ways; it is regulated by a large number of variables, and it is a by-product of communication that emerges from on-going discursive processes.

Language is a system whose structures “emerge from interrelated patterns of experience, social interaction, and cognitive processes” (Beckner et al. 2009, p. 2).

Language is a complex adaptive system that is constantly remoulded by the speakers’ interactions in ways that reflect past communicative experiences and project into current and future discourse. We take side with Ecological Linguistics, i.e., “the study of interactions between any given language and its environment” (Haugen 2001, p. 57), which defines language as an ecosystem composed of many agents that linguistically interact in their speech community in the same way as multiple agents behave in all other complex systems. Any speaker’s behaviour is hence the result of a range of competing factors that include the physical facts of language as well as cognitive and social motivations. Overtime the communicative interactions between the speaking agents produce language changes at many different levels. In Ecological Linguistics, communication provides the interlocutors with ‘affordances’. The notion of *affordance*, first developed by the perceptual psychologist Gibson (1977), refers to the actionable properties that establish a relationship between an individual (either a person or animal) and the environment: “Affordances provided by the environment are what it offers, what it provides, what it furnishes and what it invites” (Gibson 1979, p. 127). Speakers exploit affordances to act linguistically in ways that they deem useful to meet their current needs. Varela and collaborators have foregrounded the importance of interaction as playing a crucial role in affordances, which “consist in the opportunities for interaction that things in the environment possess relative to the sensorimotor capacities of the animal” (Varela et al. 1991, p. 203). Language thus encompasses the relations that speakers hold with the communicative environment. Banking on Van Lier (2000, 2004), Lantolf defines the concept of affordance as

a particular property of the environment that is relevant to an active, perceiving organism in that environment. An affordance affords further action. What becomes an affordance depends on what an organism does, what it wants, and what is useful for it. (2006, p. 252)

With this premise established, we turn to discuss the system of language, the role played by the speaking agents and the emergent outcomes of their interactions.

2.2.1 *Speaking Agents, Joint Actions, and Emergentism*

Some major features of language as a complex adaptive system shed light on language complexity in such diverse fields like language structure, language use, language change, language acquisition, and language endangerment. Beckner et al. (2009) observe that language is the outcome of diachronic and synchronic interactions between many diverse cultural and natural features, such as cognition, culture, social context, personal experience, entrenchment and embodiment.

If we adopt a synchronic perspective and observe the internal structure of language, we realize how the different levels, or sub-systems, of its organization constantly compete, merge and adapt so as to produce a coherent text. In other

words, the textual requirements involve the interactions of various sub-systems (the phonological, morphological, syntactic, lexical sub-systems), which feed into one another in ways that are instrumental to produce a text that is efficient and appropriate to the situational context. The different language levels can be conceived of as multiple agents that co-adapt their behaviours in order to synergistically produce an optimal text for the specific situation of occurrence.

If we consider individual speakers, we realize that their experience of and exposure to language culminate in their personal idiolects. The many different idiolects of individual speakers in a given speech community all together produce the speech community's idiolect, or what Beckner calls a 'communal language'. In the same way as an idiolect does not emerge in isolation but is the result of the many interactions between speakers, the communal language is the emergent product of the dynamic complex interactions among the idiolects of each individual speaker. Both the individual and the communal idiolects constantly change, co-adapt and reorganize so as to optimize communication. It is worth underscoring the fact that, when the idiolectal behaviours of speakers combine together, their result is not given by the simple sum of features, but is a vectorial product emerging from the individual interactions between speakers. Over time there occurs a constant change within speakers and across speech communities.

Once we have agreed on the fact that language is "a flexible tool which responds to the demands of communicative function and emerges from repeated exposure to instances of language in use, i.e., to naturally occurring discourse" (Butler 2009, p. 37), we can set out to consider how grammar emerges from repeated usage. Language derives from the human agents' need to communicate: in order to meet their needs, speakers engage in joint communicative actions (Clark 1996), which depend on what is usually called 'shared cognition', that is, the awareness that intentions and beliefs can be shared with other agents through language. Communication is thus a 'shared cooperative activity' (Bratman 1992, 1993) in which two or more agents jointly behave according to the set of linguistic (e.g., phonology, lexis, morpho-syntax) and pragmatic (register, genre, politeness, etc.) conventions that are well rooted in their speech community. It is important to keep in mind that, in communicative joint actions, the repetition of language patterns changes over time, thus triggering linguistic variation. It is through joint communicative actions that speakers become aware of frequent patterns and, by having recourse to probabilistic reasoning, categorize and memorize a network of grammatical instances that then they use as linguistic routines. In Hopper's words,

abounds in all sorts of repetitions that have nothing to do with grammar as it is usually understood; for instance, idioms, proverbs, clichés, formulas, specialist phrases, transitions, openings, closures, greetings, farewells, favoured clause types, and so on.

Grammar gathers all different types of routinization, i.e., repetition of lexical, morpho-syntactic and idiomatic strings of language used in speech situations. Most of language is memorized as ready-made, pre-packaged format, and continuous exposure to the statistical regularities of language patterns shape and reshape the

cognitive representation of grammar. Repetitions of cognitive events result in knowledge stored in long-term memory: frequency of use of concepts and linguistic constructions foster entrenchment, i.e., automated routines memorized as symbolic pairings of semantic and phonological structures: “Entrenchment pertains to how frequently a structure has been involved and thus to the thoroughness of its mastery and the ease of its subsequent activation” (Langacker 1991, p. 45).

Concepts and constructions become entrenched in the mind through frequent use and activation in the individual speakers as well as in the whole speech community to such an extent that this leads to a collective automatization effect (Schmid 2010, p. 119). In other words, repetition fosters memorization: the more frequent repetition is, the higher the degree of entrenchment and the stronger the automated activation. As Langacker puts it, there exists

a continuous scale of entrenchment in cognitive organization. Every use of a structure has a positive impact on its degree of entrenchment, whereas extended periods of disuse have a negative impact. With repeated use, a novel structure becomes progressively entrenched, to the point of becoming a unit; moreover, units are variably entrenched depending on the frequency of their occurrence. (1987, p. 59)

The units of language, from single morphemes up to highly complex constructions, are mentally entrenched routines representing single *gestalts* that are made up of conventional form-meaning pairings; yet, when “a complex structure coalesces into a unit, its subparts do not thereby cease to exist or be identifiable as substructures [...]. Its components do become less salient, however, precisely because the speaker no longer has to attend to them individually” (Langacker 1987, p. 59). Thus conceived of, such units show to be highly flexible in nature; speakers can hence easily manipulate and adjust them into other syntactic structures with little cognitive effort.

Entrenchment correlates with salience, and to understand the nature of their correlation a specification of salience is in need. Cognitive Linguistics distinguishes two types of salience: (1) *ontological salience*, which refers to properties of entities whereby more salient ones are better candidates for the attraction of our attention, as is the case in a situation in which a human being is climbing a tree: the person is better qualified to become our focus of attention than the tree (*cfr.* Figure/Ground alignment in Talmy 2000, pp. 311–344); and (2) *cognitive salience*, which refers to the temporary activation of concepts in our working memory during current speech processing; in turn, activation can occur through a ‘conscious selection mechanism’, as when a concept is uttered thus entering our attention focus, or through ‘spreading activation’, as when the activation of a concept (e.g., *sea*) indirectly activates a series of related concepts (*wave, beach, ship*, etc.). While ontological salience is a permanent and inherent property of real-world entities, cognitive salience is a temporary activation state of concepts. The two different types of salience hold two different types of relationship with the process of entrenchment. First, our attention is naturally drawn on more ontologically salient entities and, consequently, cognitive events prompted by more ontologically salient entities are more frequent and foster more rapid and deep entrenchment of concepts. Second,

cognitive entities that are more deeply entrenched become cognitively more salient in our attention focus and more easily they load related concepts through spreading activation in our working memory (Schmid 2010).

Since entrenchment is a function of frequency, two different types of frequency effects on the storage and processing of linguistic expressions must be distinguished: *token frequency* and *type frequency*. The former refers to the degree of frequency with which actual expressions (e.g., a single word) occur in language use; the latter represents the number of expressions that trigger constructional schemas. For example, lexical bundles are highly frequent cognitive routines that, being stored as holistic units, do not require the activation of high-level schemas, and it is token frequency that is essential for their storage and processing; instead, type frequency is necessary to develop entrenchment of constructional schemas like the ditransitive or the resultative patterns (Bybee and Scheibman 1999).

Given the fundamental role that repetition plays in the storage and processing of concepts and linguistic expressions, communication cannot be longer said to be the mere product of generative rules applied to the huge amount of possible word combinations; rather, it also and mainly consists of speech patterns, chunks, pre-fabricated sequences, constructions and mini-constructions that are entrenched in the speaking agents' mind through continuous language use (Pawley and Snyder 1983; Sinclair 1991; Goldberg 1995; Ellis 1996; Cowie 1998; Erman and Warren 2000; Boas 2003; Wray 2008). Grammatical patterns are pervasive in language, and they interplay and emerge diachronically (language change), synchronically (all levels of linguistic organization from phonology to pragmatics and genre), and ontogenetically (language acquisition and learning). The notions of patterns, or chunks, and constructions broadly share the assumption that language is fundamentally an inventory of ready-made structures filled with semantic content; however, there is no consensus on the form in which strings of language are memorized and routinized. At least two approaches are worth mentioning in this respect. Some scholars hold the view that a large part of language is routinized in the forms of chunks (Wray 2002; Ellis 2002); others conceive of language as a memorized network of patterned constructions, or even stored computational routines (Goldberg 1999; Tomasello 2003; O'Grady 2005; Auer and Pfänder 2011). These two main perspectives can pave our way to the issue of emergentism in language.

The fact that strings of language, such as 'How are you doing?' or 'Can I help you?', are memorized as holophrastic units was already advanced in *The Philosophy of Grammar* (1924) by Otto Jespersen, who had observed that many grammatical structures are fixed and that

some things in language – in any language – are of the formula character; that is to say, no one can change anything in them. A phrase like "How do you do?" is entirely different from such a phrase as "I gave the boy a lump of sugar". In the former everything is fixed [...] One may indeed analyse such a formula and show that it consists of several words, but it felt and handled as a unit, which may often mean something quite different from the meaning of the component words taken separately. [...] a whole sentence or a group of words, or it may be one word, or it may be only part of a word,

- that is not important, but it must always be something which to the actual speech-instinct is a unit which cannot be further analysed or decomposed in the way a free combination can. (1924/1951, pp. 18–19, 24)

This definition introduces notions that have become central in the fields of Phraseology (Nattinger and DeCarrico 1992) and Construction Grammar(s) (Goldberg 1995; O’Grady 2001; Boas 2003).

Patterns of language use were first noticed and described by Firth (1951), who provided the notions of *collocation*, the ‘habitual company’ of words, and *colligation*, the regular syntactic features of words. Such lexico-grammatical patterns have drawn the attention of many researchers (Pawley and Snyder 1983; Sinclair 1991, 2004; Ellis 1996; Moon 1998; Stubbs 2001; Halliday 2002; Schmitt and Carter 2004; Hoey 2005).¹ Although the language offers an infinite number of combinations, speakers do not exploit them and, instead, have recourse to a limited set of chunked elements shared by their speech community, a choice that increases also the sense of social belonging. Researchers agree on the fact that formulaic units are “stored and retrieved whole from memory at the time of use, rather than being subject to generation or analysis by the language grammar” (Wray 2002, p. 9). One of the functions of formulaic units is to reduce the processing load of the language users, who can then attend to the requirements of the situational context, or focus their attention on other types of concomitant (un)related activity (e.g., note-taking or driving a car).

In the field of language learning, formulaic language has recently been given equal importance as generative grammatical rules. Skehan (1998) advances the hypothesis of a ‘dual-coding system’, that is, a language system composed of two subcomponents: a ‘rule-based system’ consisting of generative rules and an ‘exemplar-based system’ encompassing the wide array of linguistic chunks that speakers memorize as wholes (1998, pp. 53–55). This is what Tomasello (2000) observes in first language acquisition: from the input children learn chunks that they use to gradually extract generative rules. In a similar fashion, in second language acquisition chunks are learned lexically and, on condition that learners are induced to notice and analyse them compositionally, a process of ‘syntacticization’ on the exemplar-based system triggers the development of the rule-based system (Skehan 1998, p. 90). Formulaicity is considered responsible of the development of grammar and language creativity. L2 learners first memorize linguistic chunks that overtime they decompose in their constitutive parts; this occurs with chunks that are semantically transparent and that display a compositional structure. Once they have acquired appropriate knowledge of syntax, little by little L2 learners exploit chunks so as to understand how they can creatively produce new utterances (Kecskes 2003).

Highly routinized holophrastic forms are considered part of grammar also in construction-based models of language (Langacker 1987; Fillmore et al. 1988; Goldberg 1995; Boas 2003). Language users recognize a pattern as a construction,

¹Given their wide diversity, formulae are so difficult to define and classify that more than fifty labels have been coined to depict features of formulaicity.

i.e., a (complex) sign, when they identify that a number of exemplars share some degrees of classificatory abstraction. We will devote ample room to Construction Grammar(s) in Chap. 4; here we limit ourselves to observe that it posits ‘usage’ as the fundamental feature for a description of language: hence, the most frequently used patterns, many of which are of the formulaic nature, become routinized in the speakers’ mind. In this respect the notion of mini-constructions advanced by Boas (2003, 2011) represents an insightful contribution to the theory of meaning construction and an important aspect to be considered in language acquisition. A mini-construction is a form-meaning pairing representing an individual sense of a verb; it encompasses syntactic, semantic, and pragmatic information about the types of semantic arguments (event participants) that may occur with a specific sense of a verb (Boas 2003, p. 21). Boas regards the lexical entry of a verb as

consisting of a bundle of conventionalized senses where each sense of a verb constitutes its own mini-construction. The advantage of assigning to each sense of a verb its own form-meaning pairing exhibiting specific semantic and syntactic specifications for each of its arguments lies in the fact that one does not have to postulate abstract constructions whose range of applicability is hard to determine and might thus lead to overgeneration. (Boas 2011, p. 1275)

Construction grammarians claim that routinization applies also to partially filled expressions: an utterance like ‘*Do you mind if I open the window?*’ is composed of a fixed, non-parameterizable part ‘Do you mind if I’, which is stored in the speakers’ mind as a routine to ask for permission, plus a non-fixed, parameterizable part ‘X’, in our example, *open the window* (Ruiz de Mendoza and Mairal Usón 2008; Baicchi and Ruiz de Mendoza 2010). In the case of the ‘IF I WERE YOU, I WOULD X’ construction, the fixed part is memorized as a whole, indivisible chunk that, once completed with the parameterizable part ‘X’, instantiates, in different situational contexts, different speech acts, i.e., different ‘illocutionary constructions’ (Baicchi 2012, 2015) like suggesting (‘*If I were you, I would talk to your doctor about changing meds*’), offering (‘*If I were you, I would have more tea*’), warning (‘*If I were you, I wouldn’t touch that insect*’), or threatening (‘*If I were you, I wouldn’t dare to come a step further*’). In Construction Grammar(s) also argument structure constructions, such as the double-object construction, as in Jespersen’s example ‘*I gave the boy a lump of sugar*’, is memorized in the form of the Goldbergian abstract constructional schema ‘X – pred – Y (= NP) – Z (= NP)’; or the caused-motion construction, as in “*The poor actor was laughed off the stage*”, is memorized as ‘X – pred – Y (= NP) – Z (= PP)’. A fundamental distinction is worth mentioning: while formulaic expressions and low-level forms are routinized linguistic habits and processing shortcuts that are computationally less costly, high-level constructional schemas are resorted to produce novel expressions and offer room for language creativity.

Routinized language patterns vary considerably in type and degrees of fixedness. Independently of their degree of fixedness, they become entrenched in the speakers’ mind, in their linguistic structures as well as in the frequent inferences that become part of their meaning in the speech community. We can concur with Ford et al.

(2003) when they say that “grammar is a rather loosely organized set of sorted and categorized memories we have of how speakers have resolved recurrent communicative problems” (2003, p. 120). Language patterns in fact become conventional ways of constructing meaning, of categorizing linguistic instances and of making inferences. Indeed grammar is an open-ended, complex system of forms that is constantly subject to change any time the speaking agents use it and adjust it so as to meet their communicative needs; and, as Mohanan explains,

the emergence of order/complex organization in linguistic systems is analogous to the emergence of order/complex organization in non-linguistic systems. The formation of grammar in an individual does not involve a logical problem of deducing propositional knowledge, but involves growth of form in a system that governs the external behavior of the system. Linguistic patterns appear spontaneously in the language faculty, when triggered by the environment, like patterns in snowflakes. Unlike snowflakes, however, linguistic systems exhibit adaptability. Their internal changes are governed by the pressure to conform in their overt behavior to those of the other members of the community. (1992, p. 654)

This type of systemic behaviour produces changes in meaning and forges new linguistic structures. Over time different uses of these forms develop and their frequency of use determines the outcome of new forms. Frequency of occurrence has an impact on the individual speaker as well as on the whole speech community; it fosters routinization and automatization of linguistic and cognitive units. In other words, grammar gathers sedimented forms that through usage become significantly frequent in the speech community: “The structure of language we speak sediments out of the multitudinous language events to which we are exposed in the course of our daily lives” (Butler 2009, p. 35). And yet, language is always provisional, with its structures being constantly subject to negotiation and change, always in motion toward never-reaching completeness and stabilization. Semiotically speaking, to say that linguistic phenomena arise spontaneously means that the ‘sign’ is not stable, rather it is always provisional in that it changes when speakers use it. As a consequence, repetition of discourse undermines sign stability and gives rise to novel linguistic structures. Language use is therefore responsible for emergent patterns. The phenomenon of ‘linguistic emergence’ was first postulated in Hopper’s seminal work on ‘*emergent grammar*’ (Hopper 1988; see also 2011, 2012), which has opened the way to a huge body of research in the fields of Ecological Linguistics and Usage-Based Linguistics (MacWhinney 1999; Tomasello 2000, 2003; Stefanowitsch and Gries 2003; Hoey 2005; De Bot et al. 2007; Ellis 2008; Beckner et al. 2009; Ellis and Larsen-Freeman 2006, 2009; Tyler 2010; Larsen-Freeman 2012; Larsen-Freeman and Cameron 2008; Kramsch and Whiteside 2008; Van Lier 2000, 2002, 2004). In defining emergent grammar, Hopper argues that the grammar of a language consists

of an open-ended collection of forms that are constantly being restructured and resemanticized during actual use. [...] its forms are immaterial; they have been used before and they will be used again, on each occasion of use in a different context and with a different sense. They come and go in the speaker’s awareness according to whether they are often or rarely heard, and are not totally and simultaneously available to the speaker without regard to context. They are subject to the vagaries of memory, stress, appropriateness, and changes of

topic, and to reinforcement or absence of reinforcement from interlocutors. [...] Language [...] is an emergent fact having its source in each individual's experience and life history and in the struggle to accomplish successful communication.

Emergentism in language has arisen out of dissatisfaction with the Chomskian nativism, which postulated the existence of an *a priori* autonomous Pisa: Universal Grammar. Emergentism has become a robust perspective in first and second language acquisition, whereby both develop along processes of inductive generalization (MacWhinney 1999). Speakers observe statistical regularities in the language and extract linguistic generalizations from their communicative experiences. The relationship between the relative frequency in the language input and the learning process is still a matter of debate, which divides researchers supporting a strong and direct correlation between input and learning (Ellis 2002) from researchers claiming a weaker relationship between them (Elman 2002).

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