Articles

Sciences of complexity and language origins: an alternative to natural selection[1]

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Abstract

Natural selection is claimed to be the only way to explain complex design. The same assumption has also been held for language. However, sciences of complexity have shown, from a wide range of domains, the existence of a clear alternative: self-organisation, spontaneous patterns of order arising from chaos. According to this view, design derives from internal factors (dynamic interaction of the elements within the system) rather than from adaptation to the environment by means of selection. This paper aims to apply sciences of complexity to language origins; it shows that preexisting and well established ideas can be rethought according to such a view. The main objective of the paper is to illustrate the new and promising horizons that complexity could open as regards the origins of the most specific property of human beings.

1. Introduction

Traditionally, language was considered as one of the most representative examples of cultural transmission (as opposed to biological transmission), a purely cultural phenomenon. In the second half of the 20th century, though, that conception was dramatically questioned by Noam Chomsky's Generative Grammar (see Chomsky 1986: ch. 2, and Otero 1991, 1994a for the implications and consequences of the conceptual shift), by asserting that the language faculty is biologically seated. In Chomsky's (1993: 29) words, "The child's language "grows in the mind" as the visual system develops the capacity for binocular vision, or as the child undergoes puberty at a certain stage of maturation. Language acquisition is something that happens to a child placed in a certain environment, not something that the child does" (See Pinker and Bloom 1990: 707 for a brief summary of the facts that clearly support the biological view for language).

However, for a long time there was something lacking in Generative Grammar: in spite of the great efforts devoted to show the innate basis of language from the ontogenic view, there was very little interest to extend the same reason-

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ing to phylogeny: origins and evolution of the trait in the species (excepting some isolated reflections by Chomsky, among others). However, phylogeny and ontogeny presuppose each other; they are clearly the two sides of the same coin. Therefore, phylogenic approach to language is not without its importance for linguistic innatism. Newmeyer (1998: 305) puts it clearly: "Generative grammarians have an obligation to address the question of the evolution of language".

The aforementioned lack began to be overcome around the beginning of the 1990s, when a number of influential works appeared that shared a clearly biological view for language origins: Bickerton (1990), Newmeyer (1991), Piatelli-Palmarini (1989) or Pinker and Bloom (1990), among others. These approaches strongly disagree about the role of natural selection and adaptation in language phylogeny. To summarise the situation, Pinker and Bloom (1990) and Newmeyer (1991) (see also Dennett 1995; Maynard Smith and Szathmáry 1995) claim that the work of natural selection is the only alternative to explain complex design (not only as regards language, but as regards any design). In Pinker and Bloom's (1990: 708) words, "All we argue is that language is not different from other complex abilities (…), and the only way to explain the origin of such abilities is through the theory of natural selection".

Other scholars (for example, Chomsky, Gould, Lightfoot or Otero) are quite skeptical about approaches to language origins which are crucially based on natural selection; although they do not deny that natural selection could have some role, in their opinion, language probably did not arise as an adaptation, but rather as an epiphenomenon or side-effect, as an exaptation (in the sense of Gould and Vrba 1982), a consequence of a cerebral reorganisation produced by the increase of the brain.

Chomsky's position is especially interesting for the picture developed in this paper; his scarce and isolated reflexions about language origins have had, however, a great repercussion, perhaps in part because of their confluence with Gould and Lewontin (1979), where the abuse of adaptationist explanations is denounced, and "incomplete" (p. 147) alternative forces to natural selection are suggested. Although Chomsky does not completely reject natural selection (for example, Chomsky 1980: 239 states that "Language must surely confer enormous selectional advantage"; see also Chomsky 1975: 252), he has repeatedly suggested that language may be a by-product of the increase in cerebral complexity (see Otero 1990, 1994b). The problem of language origins may have to do with "certain physical laws relating to neuron packing or regulatory mechanisms" (Chomsky 1980: 100). Thus, "the answers may well lie not so much in the theory of natural selection as in molecular biology" (Chomsky 1988: 167). Otero (1990: 750, fn. 4) quotes a clear reflection of Chomsky about the issue:

> It is possible that language is best explained in these kinds of terms: a carry-over effect appears at a certain order of brain complexity. Or, to put it differently, at a certain lev-

> el of complexity many of the human brain's most striking capacities may have to do with the laws of physics. They may relate to the density and packing of neurons in the brain, for example (…). It might turn out, in fact, that simply as a consequence of physical law, the brain will have language ability, just as a certain molecular organization will eventually result in a crystal.

Lately, much work has been developed in a line along the same path in the so-called sciences of complexity; this interdisciplinary theory tries to explain patterns of complexity not from the environment (i.e., not built up by natural selection), but rather as a consequence of internal laws yielding self-organisation of the system, a spontaneous order arising from chaos. Pinker (1997: 197) claims that there are only two alternatives for complex design: God or natural selection. However, at least a third one comes to the fore: complexity. The main aim of this paper is to take into account the impressive achievements of sciences of complexity in a wide range of domains (which go beyond biology and natural sciences), and, furthermore, to explore the horizons they offer for the study of language origins. Although my starting-point is that of Chomsky, it must be noted that I will adopt a more specific view than the one suggested by this scholar (a view which, anyway, he has not developed at length); as pointed out above, he claims that language could be a result derived from neuron packing; my picture will transfer his ideas to a framework taking into account a protolanguage based on representational capacities (Bickerton 1990, 1995; Maynard Smith and Szathmáry 1995, etc.).

The article is organised as follows: section 2 offers a brief sketch of the main assumptions of sciences of complexity, which do not reject Darwinian ideas, although they put limits on their effects. Section 3 aims to apply this theory to language origins, showing interestingly that it is possible to rethink preexisting and well established ideas according to sciences of complexity. Section 4 offers one clear advantage of this view with regard to the one which concentrates on natural selection. Section 5 summarises the main conclusions.

2. Natural selection and complexity

The theory of natural selection (Darwin 1859) is one of the more important ideas of scientific thought, although it is quite simple if considered in itself: it means survival, and differential reproduction of genetic variability of organisms, associated to their fitness. For natural selection to apply, three conditions are needed: existence of genetic variation, differences in fitness of variation, and transmission by heredity of the trait. Genetic variation (arising from mechanisms of mutation and recombination), which is the source of natural selection, has a highly relevant role in the adaptation of organisms to different environments, although the environment itself does not trigger mutations, which are at random. As Dobhzansky (1970) put it clearly, genes do not know how and when it is good for them to mutate (see Futuyma 1998). For this reason, the role of natural selection is to accept or to reject new random genetic variations (Dawkins 1986).

Natural selection has been taken as the only possible explanation for adaptive complexity in biology. The only way to reach complex design is by means of little random mutations stored by their effect in the fitness of the organisms. The evolution of the eye, containing different and highly specialised parts, has became a paradigmatic example (see Dawkins 1986); as Pinker and Bloom (1990: 710) point out: "no physical process other than natural selection can explain the evolution of an organ like the eye. The reason for this is that structures that can do what the eye does are extremely low-probability arrangements of matter". Therefore, its development was due to small and random changes that were gradually improving the organ. Thus, "Evolutionary theory offers clear criteria for when a trait should be attributed to natural selection: complex design for some function, and the absence of alternative processes capable of explaining such complexity" (Pinker and Bloom 1990: 708). However, the results of sciences of complexity do not fit well with the supposed absence of alternative processes to explain complex design.

Sciences of complexity (see for a survey Kauffman 1993, 1995; Lewin 1992; Waldrop 1992) derive from the tradition of Rational Morphology, which sought to find laws of form to explain patterns of order and regularities in nature. Sciences of complexity assume that laws of organisation do not lean on factors arising from external pressures (adaptation by means of natural selection); instead, such laws are based on self-organisation of complex systems, produced by the system itself, abruptly generating spontaneous patterns of order. A classic example was offered by Thompson's (1917) discoveries about how shapes of different species could be generated with simple mathematical transformations altering a minimal number of parameters on geometric coordinates; these findings seem to point to physical laws which are independent from the work of natural selection.

Sciences of complexity study the behaviour of complex dynamic systems, composed of a network of many elements, that, accordingly, have many possible states. In spite of the number of states, self-organisation arises as a natural property, i.e., well defined patterns emerge spontaneously, giving rise to order in the system from previous chaos (which does not imply randomness, but absence of organisation; see below). A system with these characteristics abandons chaos spontaneously, not governed from outside, to settle at the edge of chaos. In this space, a rich and complex activity abruptly arises which is unpredictable (a feature of nonlinear dynamics) from the individual parts. Following Goodwin (1994: 183), the reason why the system settles at the edge of chaos is that in that area all the parts of the system are dynamically communicated with all other parts, which implies a maximal potential for information processing.

Let us take, for the sake of argument, a simple and clear example, related to one of the most complex behaviours found in the animal kingdom: eusociality (i.e., cooperation and seeming altruism) of social insects (see Wilson 1971). This behaviour has worried many researchers, because altruism apparently held a threat over the dominant view of the selfish nature of genes (which would be popularised by Williams 1966 and, especially, Dawkins 1976): altruism puts into risk the genetic future of an organism. Let us take into account that, for example, worker ants sacrifice their potential for reproduction for the benefit of their mother, and they rear their sisters instead of daughters. Hamilton (1964) proposed a solution to altruism and cooperation, inclusive fitness (or kin selection), which became the leading hypothesis for explaining eusociality: natural selection, by means of haplodiploidy (males are haploid, developing from unfertilised eggs, and females are diploid, which means that they develop from fertilised eggs), favours the evolution of eusociality. For females, it is a better solution to rear sisters than to rear daughters, because they share more genes with their sisters than with their possible daughters. That would be, according to Hamilton, the keystone for eusociality.

Science of complexity, however, may become relevant to the issue: sociability, cooperation, altruist behaviour, are fundamentally related to the dynamics of a complex system, as Goodwin (1994) convincingly shows for ants. Their activities, if considered individually, are chaotic, lacking any kind of organisation and of intelligent behaviour. However, if the number of individuals increases, the patterns of activity of the ants radically change, and an abrupt transition from chaos to order arises. Interestingly, this emergence of order takes place when the density of the colony reaches a critical value: if the density is low, few meetings between ants take place, but when it augments, activity extends to the whole colony. As Goodwin (1994: 71) claims, this emergent behaviour cannot be predicted from the behaviour of individuals (i.e., nonlinear dynamics).

This simple illustration allows us to appreciate the main characteristics of systems sciences of complexity are concerned with; the theory is supported by much theoretical work in domains and issues, each very different from the other, but all of them sharing the basic feature of self-organisation: boolean nets, origins of life, cellular types and composition, constraints on biological shape, macroevolution, ontogeny, vision, embriology, chemistry, technology, formation of human societies, and even literature and literary theory, among others.

I have mentioned that the system organises within the space placed at the edge of chaos, where an activity arises that produces a maximal information processing. A crucial notion for the system to be settled within that area is that of attractor, similar to the 'phase transition' of physics. Lewin (1992) offers this clear comparison: an attractor would be the rough equivalent of a sea whirlpool, which attracts what approximates it. When the system changes, increasing, for example, the number of its elements, it enters suddenly in a phase transition, i.e., some attractor captures it, forcing it to abandon the territory of chaos, thus entering into an ordered pattern. In other words, attractors are the source for emergent spontaneous order, the source of complexity (Kauffman 1995: 79,90).

The notion of attractor as the source of order suddenly arising in an unpredictable way (i.e., it is not possible to predict the whole pattern of activity from the isolated elements) has significative repercussions. The so-called synthesis of evolutionary theory (mainly due to Dobhzansky, Mayr, and Simpson), the result of the combination of Darwin's ideas with the knowledge about genetic heredity, was able to offer a solution for a problem Darwin could not satisfactorily solve: the idea itself of natural selection depends on the existence of variations that can be inherited; selection operates on these variations. However, Darwin did not know how such variations took place; the solution became available with the advances offered by genetics. Within the synthetic theory, the biological field seemed to be explained by means of selection: random mutations, combined with genetic variations and heredity, were the reason that fitter organisms transmitted more of their genes, as opposed to less fit organisms. Thus, traits, and, in general, variation among species is conceived as an addition of historical events, i.e., common ancestors (see, for example, Dennett 1995: ch. 5; this scholar faces up to the issue with brilliant dialectics, but historical factors step in to explain constraints in the space of design).

Scientists of complexity do not agree with such a view; in fact, they point out that this reductionist picture has turned biology into a science of the accidental (Kauffman 1995: 7; see also Goodwin 1994: 146). As we have seen, natural selection operates from randomness, i.e., fortuitous variation produced by mutations and recombinations. Although selection is not equivalent to randomness, but to survival of the fitter organisms on adaptive grounds, chance is the only source for the genetic text to be modified (Monod 1970). However, this view prompts a question without a satisfactory answer: if variations are at random, we should expect an almost infinite variation among organisms (with the only limitation of certain mechanical requirements). If, as Goodwin (1994: 87,146) claims, in random variations anything can happen, any biological form would be possible, the only principle at work being survival through adaptation. However, this does not follow, and, sometimes, constraints about shapes clearly surpass the probability of the mere coincidence. Chomsky (1982: 23) asserted that "there are not many kinds of possible organisms", and indeed this seems to be the case. Taking an example from Goodwin (1994: 116 and ss.), there are 250,000 species of higher plants, which show a strong diversity concerning leaves and flowers; however, in spite of such a diversity, there is an important degree of order in morphology; for example, phyllotaxis (arrangement of leaves on stems) is reduced to only three patterns. We should expect the existence of many different patterns, given random variation, and also given the so different environments higher plants are supposedly adapted to.

As opposed to this view, sciences of complexity assume that the state space (i.e., space of possibilities) is constrained not by historical factors, but by attractors (hence the relevance of this notion), generative principles of nonlinear dynamic systems, which yield self-organisation. Therefore, the factor which may explain many differences in macroevolution (and also in the rest of domains) is not selection nor adaptation to the environment, but self-organisation of complex systems (an excellent example is offered in Kauffman 1995: 43–45 about the improbability of appearance of life from randomness).

Thus, state spaces are constrained by self-organisation, which makes many of the logical possibilities unavailable. Let us take a linguistic parallelism which may help to clarify the notion of state space; we could think of the space of possible grammars within Generative Grammar (the logical problem of language acquisition). If no additional constraints are postulated, such a space is much too huge for the child to converge on the target grammar (see Baker 1979; Baker and McCarthy eds. 1980; Wexler and Culicover 1980 among many other references). However, the learner is supported by innate principles which strongly constrain the space of logical grammars, in such a way that the search by wholly random resolution can be avoided. The same applies to the notion of state space within sciences of complexity: among many possible state spaces, the system does not have to explore randomly all of them, spontaneously arriving to a few robust results (attractors).

Consequences should be clear: for sciences of complexity, order does not emerge from randomness, from accidental factors, the raw material of selection. However, this does not deny the role of selection and adaptation. In fact, it is assumed that this role is able to offer an account of variations on a small scale (microevolution), but it cannot explain the great differences in the shapes. Selection is a filter that rejects the utter failures (Goodwin 1994: 157). Generative principles of self-organisation which give rise to complexity are more suitable to understand both structure and form. To sum up, selection does not originate complexity; instead, it operates on it. As Kauffman (1995: 188) puts it, "that which is self-organized and robust is what we are likely to see preeminently utilized by selection".

It is not a purpose of this section to present systematically the assumptions of interdisciplinary sciences of complexity, but to characterise briefly their main aspects, which will become relevant in section 3. What I would like to emphasise from the aspects referred above is that Pinker and Bloom's (1990: 708) assumption that "The only successful account of the origin of complex biological structure is the theory of natural selection" (see also Maynard Smith and Szathmáry 1995; Dawkins 1986; Dennett 1995 among many others) must be questioned: sciences of complexity have shown that there is indeed an alternative to natural selection.

Kauffman (1995: 28) states that:

> I Suggest (…) how life may have formed as a natural consequence of physics and chemistry, how the molecular complexity of the biosphere burgeoned along a bound-

ary between order and chaos, how the order of ontogeny may be natural, and how general laws about the edge of the chaos may govern coevolving communities of species, of technologies, and even of ideologies.

In the same way as sciences of complexity have been applied to a wide range of domains, going beyond biology and natural sciences (in this regard their application to literature and literary theory is highly representative; see Hayles 1990), this paper aims to sketch the new horizons they can open as regards the study of language origins; in the same spirit as in the rest of fields related to biology, complexity could become an alternative to natural selection that is worthy of serious consideration.

3. Complexity and language origins

As pointed out before, scientists of complexity do not accept selection as responsible for the making of complex designs; rather, they point out that laws of order are yielded by internal factors giving rise to self-organisation. I would like to suggest that this view can also hold for language, in such a way that it is possible to give an opening to that kind of non adaptationist processes. Although this claim may be surprising, we shall see that it is possible to reinterpret reasonable ideas in the light of sciences of complexity without great efforts.

Let us consider again the notion of complex nonlinear dynamic system, which, by the way, would have been considered an aberration according to Newton's framework. A linear system is basically one whose behaviour can be predicted with an absolute probability; for example, laws of movement are predictable, because their behaviour can be anticipated; this is the reason that a rocket can reach the Moon, taking the example offered in Lewin (1992: ch. 1). However, the effects of a nonlinear system cannot be anticipated, because the behaviour of the overall organisation cannot be predicted from the behaviour of its individual elements. This is the case of life, as Kauffman (1995: 24) claims; although its different parts are just chemical components, the emergent property has a very different feature: to be alive. This property cannot be located in any of its parts, but in the emergence of the whole. In the same spirit, the behaviour of the emergent order of the colony of ants (and, more generally, of eusociality) is not predictable from the behaviour of each individual. Again, properties of the system have features unexplainable from its isolated components.

The same characteristic can also hold for language, in such a way that the language faculty can be seen as a complex nonlinear dynamic system from the phylogenic view. I will argue that it is not possible to predict the behaviour of the emergent system (such behaviour being understood as the enormous range of possibilities full language offers to us) from its initial and isolated elements (understood as a pre-existing set of words or protolanguage).

Approaches which try to explain language origins from natural selection, i.e., as an adaptation, accordingly underline communicative advantages of language (see Pinker and Bloom 1990 or Newmeyer 1991). Thus, in this view, language gradually evolved from interaction with the environment. Such a view, as we have seen, is not compatible with the assumptions of sciences of complexity.

However, there is a starting-point which is an obvious candidate to be considered from the perspective of complexity. Although language is doubtless very relevant from the communicative view, it can also be considered on representational grounds (Bickerton 1990; Jerison 1973; Maynard Smith and Szathmáry 1995, among many others). In Maynard Smith and Szathmáry's (1995: 284) words, "Humans use language for communication, but it may well be that the most important aspect of language is that it is used for internal representation in the brain". Although this view is obviously not independent from the environment, since the representational capacity applies to different aspects of the environment, it presupposes internal analyses which, as we shall see, do not need the crucial help of the environment (an external selective force) for language to emerge. For this reason, it is this view that can be related to sciences of complexity for language origins. I will adopt this starting point, by assuming that the representational view is necessarily previous to the communicative one.

All species own representational capacities, more or less effective according to the capacities and the genetic programme of each one. However, for almost all species, representations are directly linked with their immediate environment (Bickerton 1990, 1995); this implies that the only representations which arise are those directly related to the satisfaction of the requirements derived from the ecological niche (conditions under which a population can persist). The relationship between environment and representations is made through concrete stimuli; in other words, their model of reality evokes responses. This does not mean denying internal states for species (as opposed to behaviourism), but asserting that a stimulus triggers an automatic internal response. However, things are very different in our species: human communication by means of language is unique, because it allows us to refer to any situation, whether or not relevant for the strict satisfaction of the ecological niche. In fact, we can refer to everything, even non-existent, imagined situations or notions, which implies, following Chomsky (1988: 183), that our ancestors "could go beyond just reacting to stimuli". This is only possible because of our representational capacity; communicative capacities are subordinated to those representational ones, in such a way that we only can communicate something unreal if we previously can imagine it, represent it. Deacon (1997: 21) is clear enough about this singular trait: "We inhabit a world full of abstractions, impossibilities, and paradoxes. We alone brood about what didn't happen, and spend a large part of each day musing about the way things could have been if events had transpired differently". The main basis for this capacity is that we have mental states where analyses are made in a different way: analyses evoke properties but not reactions (a clear example is the subject-verb distinction). This is the basis of the constructional learning claimed in Bickerton (1990), which even allows us to imagine non-existent situations.

As is well-known, important efforts were devoted to try to teach language (in different forms) to apes. Although the issue was for a long time controversial (let us note that apes were claimed to have linguistic capacity), two conclusions can be raised from those attempts: first, apes have symbolic capacity at a degree, and even constructional learning, but restricted to the presence of elements (see Bickerton 1990: 160); the second conclusion, which deals with the specific linguistic capacity, has been clearly a failure: apes cannot learn even the most basic properties of language (see Pinker 1994: ch. 11 for a survey, and Premack 1990, as a significative example of the abandonment of his previous theses). Chomsky (1980: 57) summarises clearly both points: "higher apes, which apparently lack the capacity to develop even the rudiments of the computational structure of human language, nevertheless may command parts of the conceptual structure just discussed and thus be capable of elementary forms of symbolic function or symbolic communication while entirely lacking the human language faculty".

Many scholars do accept, on different frameworks and assumptions, these symbolic capacities for apes (see Bickerton 1990; Deacon 1997; Chomsky 1980; Savage Rumbaugh 1986, etc.), mainly manifested in laboratory works. In our ancestors, as opposed to apes, evolution favoured a (slow) increase in the number of representational elements, and the appearance of different types or categories of representations ("Representations invariably lead to the formation of categories"; Maynard Smith and Szathmáry 1995: 284), together with their placement in cerebral areas different from the motor areas (see Bickerton 1998).

These representations gave rise to a protolanguage, a link between those representations or concepts and labels for them (assumed by very different lines of reasoning, like Bickerton 1990, Pinker 1994, Deacon 1997 or Maynard Smith and Szathmáry 1995), with very different properties from those of full language. This story has been referred to many times, and it is well-known; for this reason I will not be exhaustive (see Bickerton 1990, 1995 for a complete picture). Suffice to say that protolanguage consisted of a lexicon and conceptual relations, based on concepts and not on concrete entities, where actions and events were decomposed into different properties (as opposed to the holistic representation in animals). However, it probably failed to organise or link its different elements productively. As suggested above, this capacity could evolve driven by purely representational forces rather than based on communicative forces (perhaps, with communication as a by-product), as a way to process data and analyse them.

Thus, we arrive at the crucial step: emergence of full language. Proponents of the work of natural selection defend the view that protolanguage and language are linked through a gradual change, different successive steps, or intermediate grammars. Contrarily, other scholars, like Chomsky, Bickerton (1990, 1995) or Berwick (1998), the last from the framework of the Minimalist Program, assume a sudden change.

It is here where complexity may become relevant: the gradual increase in the number and types of representational units could yield a self-organisation of the system. That is, a critical mass of representational units could give rise to an emergent order, from which basic features of the computational system of language (recursivity, hierarchical structure, i.e., syntax) would be derived. This situation would lead to an optimisation of the representational capacity.

Some further points arise here: first, as pointed out, self-organisation was related to internal factors, to the dynamics of the system itself, rather than being related to the environment (communication), as defenders of natural selection claim: it was the pressure itself of representations that gave rise to a way of self-organisation, unavailable in protolanguage, to handle those elements more easily. The role of the environment is limited: although the internal capacity to represent obviously was applied to the aspects of the environment, the phase transition is not related to any selective force or pressure, but to the system itself. Futhermore, this emergent order, which introduced systems of hierarchisation, could produce strong repercussions on both the thinking and the representational capacity, yielding the maximal power of both. In fact, as suggested by Tattersall (1998: ch. 5), almost all cognitive power we own is related to language. In this sense, my previous suggestion that language can be seen as a complex nonlinear dynamic system can be perceived: the behaviour of the system (understood as the possibilities opened by full language) after the emergence of self-organisation cannot be predicted from the isolated elements, a set of lexical elements of protolaguage. As Bickerton (1990: 160–162) claims, constructional learning supported by language is what allows us to infer about absent, or simply, non-existent aspects; in this way, it is possible for language (not for protolanguage) to generate its own concepts, without basis on reality. From the view of complexity, the system settles at the edge of chaos, because it is in this area where a maximal potential for information processing is attained: the same reason may hold, as I have suggested, for language: the power to represent everything, by means of an unlimited combination of representations (i.e., syntax).

Let us note another important point: sciences of complexity have shown that great qualitative changes are not necessary for the emergence of order. Remember that, for ants, a critical mass (i.e., density) triggers the emergence of the overall self-organisation. This pattern recurs in many unrelated domains, where the number of elements is the keypoint for the system to be settled at the edge of chaos. Little elements offer a low pattern of intensity, but an increase in the number of elements yields a critical value triggering umpredictable reactions: the important point is that a quantitative change triggers a sudden qualitative change: emergence of order. The same is suggested for language: a continuous increase in the number of representational elements could trigger the emergence of order in the only species where the appropiate conditions were available. Again, we have the phase transition, or attractor.

It is interesting to note that, even from very different assumptions, some scholars offer a picture which does not differ in its essence from the view just sketched above. For example, in a recent paper, Nowak et al. (2000) propose a mathematical evolutionary model where natural selection guided the evolutionary dynamics from non-syntactic to syntactic communication. These authors claim that to communicate about events offers an increase in fitness; however, syntactic communication is not always an advantage; it is only in situations where there is "an increase in the number of relevant events that could be referred to" (p. 497). What led to syntax in our species was such an increase (p. 496), and in such a way that it was possible to formulate sentences not learnt before (at heart, they point to a economy issue; if not many events can be referred, syntax is much too an expensive procedure). The most important aspect is that they also point out a critical mass of elements as the key-point, although from communicative assumptions (they should not leave behind, though, that their assumption by which the events that can be referred, i.e., communicated, necessarily presupposes the capacity for the events to be represented, or categorised): "according to our model natural selection can only favour the emergence of syntax if the number of required signals exceeds a threshold value" (p. 495). Needless to say that the framework pointed out by these scholars has strong differences with the one developed in this paper, differences related to the role of the environment through communicative advantages, and the emergence of syntax through gradual steps. However, the confluence on a critical value as regards the emergence of syntax (i.e., language) is worth noting.

To sum up, Pinker and Bloom (1990: 720) claim that "it is certainly true that natural selection cannot explain all aspects of evolution of language", although it is able to explain the main aspects, which yield its complex design. The approach developed in this paper defends the opposite view: some role for natural selection must be accepted, because, as Chomsky puts it, language has an obvious adaptive value. However, natural selection would have operated on complex design, but it would not have originated either complexity or its emergence. This emergence would be related to capacities independent from communication or previous to it, and communication itself could derive from such capacities. It is relevant here to repeat the words of Maynard Smith and Szathmáry (1995: 284), "Humans use language for communication, but it may well be that the most important aspect of language is that it is used for internal representation in the brain". In this sense, as Jerison (1973) suggested, language as a communicative tool could appear as a side-effect of its basic function: to build up reality in an internal way (and, also, to build unreality). Perhaps some aspects could have been guided by natural selection in the translation to communicative grounds (parsing, etc., but see Lightfoot 1999: 239 and ss. about one clearly maladaptive condition of Universal Grammar), but selection itself would not yield organisation; self-organisation would arise from the dynamics of the system itself. In fact, apparent diversity and subjacent unity of language are also other features in accordance with assumptions of complexity: robust organisation although moulded in their details.

4. Selectionist explanations and the poverty of data

In the previous section, a speculative picture has been sketched for language origins from the theoretical background of sciences of complexity. This treatment emphasises a self-organisation of representational elements, as opposed to an adaptation closely related to communication claimed by defenders of natural selection; such a treatment can overcome the main objection to adaptive explanations, which makes this view untenable. Newmeyer (1998: 305) states that Chomsky "has, in general, been extremely reluctant to point to any external forces shaping the design of UG". This resistance is not surprising, as we shall see.

The main motivation for linguistic innatism is not the existence of features shared by all languages, i.e., linguistic universals, but instead, the poverty of data (Plato's Problem; see Chomsky 1986, 1988; see Lightfoot 1981 for an example of the misunderstanding). The language learner succeeds in converging on the target grammar in spite of the lacking linguistic environment, thus solving the logical problem or projection problem; this fact points to an innate structure. The following quotation from Chomsky (1968: 159) illustrates the issue clearly: "The child must acquire a generative grammar of his language on the basis of a fairly restricted amount of evidence. To account for this achievement, we must postulate a sufficiently rich internal structure (…)".

Some scholars who defend the poverty of data for ontogeny (see Pinker and Bloom 1990: 719; Newmeyer 1991: 12 and ss.; Maynard Smith and Szathmáry 1995: 289–290), do accept, however, an adaptive view for language phylogeny where the poverty of data was not relevant; language learning was possible without the innate specific structure. For Pinker and Bloom (1990: 719), this disagreement between both approaches is expected: "language evolution and language acquisition not only *can* differ but (…) they *must* differ" (italics: SP and PB). (It is highly relevant to this regard that Bates and MacWhinney (1990: 727), in their comment on Pinker and Bloom (1990), assert that "they have moved, far more than they realize, into the camp of the linguistic functionalists"). For Pinker and Bloom (1990: 719), the supposed reason at work is as follows: "Evolution has had a wide variety of equivalent communicative standards to choose from (…). This flexibility has been used up, however, by the time a child is born; the species and the language community have already made their choices".

Pinker and Bloom (1990) appeal to the so-called 'Baldwin effect' (see Baldwin 1896, and, for a recent survey, Turney et al. 1996 and references therein) for explaining such divergence. This effect basically implies phenotypic plasticity, by which organisms can adapt to their environments. The effect causes that a learned behaviour may become instinctive over time. Thus, "When some individuals are making important distinctions that can be decoded with cognitive effort, it could set up a pressure for the evolution of neural mechanisms that would make this decoding process become increasingly automatic, unconscious, and undistracted by irrelevant aspects of world knowledge" (Pinker and Bloom 1990: 722).

However, this picture is clearly contradictory: the explanation for language origins depends upon the environment, although both scholars recognise that acquisition in ontogeny is not possible by solely appealing to the environment. In this regard, the behaviourist psychologist B. Skinner may throw some light; Skinner (1966) (this paper was pointed out to me by C. Otero) asserts the identity of processes at work both in phylogeny and ontogeny: "A "mental apparatus", for example, no longer finds a useful place in the experimental analysis of behaviour, but it survives in discussions of phylogenic contingencies" (p. 1208); "Ontogenic and phylogenic behaviours are not distinguished by any essence of character" (p. 1210). Although behaviourist assumptions were shown to be false by Chomsky, the parallelism among phylogeny and ontogeny claimed by Skinner is coherent (as it would be otherwise to defend natural selection for language origins denying the poverty of data in ontogeny). Unfortunately, the same does not hold for the picture of Pinker and Bloom and the other adaptationists (such as Newmeyer or Maynard Smith and Szathmáry): without the support of innate constraints, language acquisition in ontogeny cannot be successful, but in phylogeny it was possible to learn without that support. As Ninio (1990: 747) realises, "Pinker and Bloom put themselves into the uncomfortable position of postulating a language system that is at the same time learnable from the environmental input if the learners are prehistoric, and no longer learnable when the learners are our contemporaries".

The approach developed in this paper could avoid the problem. Communication would be a side-effect of the main motivation, self-organisation of a representational system. From this view, the fact of the impossibility of language learning from the environment in phylogeny would not be surprising; in other words, the poverty of data of a system not directly related to communicative grounds would not be surprising; in this way, it is possible to unify, as in Skinner's coherent approach, although in an opposite line to the one defended by him, both phylogeny and ontogeny. We should note that the difficulty raised for selectionist approaches cannot be considered an example of what Dawkins (1986) calls the 'Argument from Personal Incredulity'; in fact, it is a really serious objection against the adaptive view for language origins, and, as suggested, it could be overcome from the view of self-organised complex systems.

5. Conclusion

Natural selection is claimed to be the only way to explain complex design. Correspondingly, a number of linguists and biologists (Pinker and Bloom 1990, Newmeyer 1991, Dennett 1995, Maynard Smith and Szathmáry 1995, etc.) have argued that the same applies to language.

Chomsky has been reluctant to accept the central role of natural selection in language origins, pointing out that language could be a side-effect of an increase of brain complexity. Interestingly, lately much work has been made in a similar line to that suggested by Chomsky within sciences of complexity. Their main purpose is to explain complex design not from adaptation to the environment by means of selection, but as a consequence of internal laws that give rise to self-organisation, creating spontaneous order from chaos.

This paper aimed to develop the above-mentioned Chomskian idea, trying to integrate it within the last developments of this theory; my approach, though, suggests a more specific view than the one by Chomsky; it departs from a protolanguage based on representational capacities. The pressures are not external, related to communication (a side-effect), but motivated by the system itself. A critical value in the mass of representational elements could yield a phase transition giving rise to an emergent order unpredictable from the individual parts. This view, which rethinks well established ideas according to sciences of complexity, could solve a strong problem raised by the adaptationist approach.

To sum up, although the proposal offered in this paper is necessarily speculative and its theses are incomplete in details, the main aim of the paper was to show that there is an overall alternative to natural selection which can be perceived in many domains; this perspective, if applied to language, could open new horizons as regards the study of its origins.

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Notes

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