euresis journal

euresis
Association for the Promotion of the Scientific Endeavour

Volume 4
Winter 2013

journal homepage
www.euresisjournal.org

The "stem mind": Reflections on human brain and language

Andrea Moro

IUSS Center for Neurolinguistics and Theoretical Syntax (NeTS)
andrea.moro@iusspavia.it

Abstract

We all have a personal theory of language. Virtually every epoch and culture formulated a major theory about the nature of language. Nevertheless, the history of the reflections on language does not proceed in a linear fashion. There are many theories of language: some pertinent, others debunked, others still are recurrent. But we often do not realize that, and for language, as well as for the sky, each of us builds his favorite constellation.

1. Like a starry night: at which point are we in understanding language?

We all have a personal theory of language. It is not as in physics or chemistry where a certain reverential fear for the nature of observable phenomena holds us from formulating explanations. With language things work differently; maybe for the simple fact that we all speak, perhaps for the abundance of data, the fact is that we feel entitled to have an "explanation" of this phenomenon. This state of affairs regards not only us as individuals, but the entire cultural path of our civilization throughout the centuries. The result is an unique overabundance of conceptions in the entire history of thought: virtually every epoch and culture formulated a major theory about the nature of language, to the point that by following its development we gain access to the "spirit of the time," as if it was a Homeric question on the history of man. We are indeed before a very special situation.

Nevertheless, the history of the reflections on language does not proceed in a linear fashion. And to contemplate it is somehow similar to looking at a starry sky, where the stars we see are the opinions which characterize the reflections on this dominion. The resulting effect is similar as well. When we look at a starry sky we cannot avoid establishing patterns among

the brightest stars. If we are not experts – or at least conditioned – each one of us constructs his own constellations, some of them obvious, others hard to grasp. But the night sky has still another particularity. We know, in fact, that not every star we see is still necessarily active: the light that arrives to us is ancient, and could have been traveling while the star has already died. The sky is therefore similar to a museum of natural history and a zoo at the same time: side by side with living animals we see the signs of those who have already gone.

Our constellations, therefore, are not only fundamentally arbitrary, but are also partial mirages, made up of ghosts of stars. The very same is true for theories about language. There are many such theories: some pertinent, others debunked, others still are recurrent. But we often do not realise that, and for language, as well as for the sky, each of us builds his favorite constellation. Obviously, as for the traveler, not all constellations are useful to planning a route: only the test of reality can verify the hypothesis (and hopes).

2. The "stem mind": which are the premises to understanding the relation between language and brain?

That language depends on the brain is not at all an obvious thing. It is enough to think that Aristotle maintained that the brain was some form of radiator of the body, whereas the cognitive faculties such as passion, memory and language dwelt in the heart. The history of the relation between language and the brain is long and choral, and by no means concluded: on the contrary, it is only now that we start to glimpse, not the answers, but the right questions for which to search for an answer. In this blind path, once understood that the brain is the organ controlling language, a first fundamental result came in the second half of the XIX Century. Paul Brocca, basing himself on the results of an autopsy in a patient presenting a selective language disorder, was able to associate a precise part of the brain to a linguistic capability [1]. The road to neurolinguistics has, from then on, proceeded at a large pace, with new techniques and models [2]. But to understand the surprising results of modern research it is necessary to recognize a second fundamental step in this path. This came about in the 50's, when Noam Chomsky, concentrating on the capacity of composing words to form phrases (the syntax), discovered the fundamental mathematical properties of human language [3].

The complexity of these synthatic properties and their invariance among world languages lead to the hypothesis that they should be biologically determined, and not a result of arbitrary cultural choices and conventions. The spontaneous learning of language by young children could thus be explained in a revolutionary way as a kind of selective development, instead of a constructive one. In other words, the child is born with a so to speak "stem mind" which contains all possible grammars. His brain, reacting on the basis of experience, selects

only the data compatible with that language spoken in his community, thus fixing it as its mother tongue during a limited period of its hormonal development. The system of rules admits a small number of degrees of freedom: the macroscopic differences among languages are thus reducible to the effect of microscopic differences in a highly complex system such as the human language [4].

Today the new challenge isn't anymore understanding that human language depends on a selective brain network, but rather to know if the properties of the code that constitutes it are conditioned on these circuits or instead are arbitrary, being able to assume any conventional form. A first attempt to an answer was obtained by verifying the reactions of the brain to certain synthatic rules that contradict the mathematical properties which are a common base to all human language. The process was divided in two phases: first, to understand which are the fundamental properties of these rules; and then to ascertain if and how these properties got expressed on a selective way in the brain.

3. The infinity present: what are the fundamental properties of human language in comparison to that of other animals?

Do animals speak? Certainly all animals communicate in some way. If by communication we mean exchanging information, even the poppies communicate. The right question then is not if animals communicate, but if they do so using codes which are similar to ours in structure. And in this sense it seems they don't. In support to the intuitions we might have on the nature of the human code, are observations that go back in an explicit and systematic way as far as Descartes, who pointed out that the capacity to produce sequences of words was an entirely and exclusive human one [5]. This is the very first property of this code: that given three words, such as "Cain", "Abel" and "killed" an Englishman can form two phrases of completely different meanings: "Cain killed Abel" and "Abel killed Cain." This capacity (namely syntax) is therefore the first watershed between human beings at one side and *all other living beings* at the other [6] – basing ourselves on a properly chosen sample, of course.

In the 70's, with a very elegant experiment, it was shown that the chimpanzee, so similar to us in so many aspects, were able to learn a considerable number of words (circa 130) but they could not use the sequence of words to compose different meanings. In general, if the animals use sequences of signals, these sequences are either fixed and non-expandable or do not change meaning when shuffled [7]. That is to say: human beings have dictionaries of words, but the animals, at most of phrases.

But which are the common properties to all (and solely) human languages? There are at least three fundamental ones. This first property – in a certain sense a premise – is that syntax is made out of a combination of discrete elements (the words); that is, small and self-contained

blocks of a finite quantity of information. There are then two properties related to the combination of words, the syntax in itself [8]. Let's look at them by means of a few simple examples.

When we form a phrase, we know that the words enter in relation to each other in a selective way. For example, if I say "John runs", I recognize that the verb and the noun are both in the singular. The phrase "John run" would be wrong. But the sequence "John run" can be made perfectly acceptable if the word "John" is preceded by other, appropriate words, such as "the friends of" in "The friends of John run." In this case, the verb ignores, so to speak, the name that precedes it and agrees with the name that is farther from it. This "distance relationship" can of course be extended at will, given the limits of memory and physical energy available. It suffices to think of a phrase such as "The friends that my sister said the magician thinks are relatives of John run." Therefore, a first property of syntax is action at a distance between two words, without limits on the number of words that separate them. And this property tells also that the linear order of the words don't really count.

The second property consists on the fact that in between two words which enter in a certain relation there can be other that come to be part of the *same* relation they share. If we take for example two words such as "if" and "then", we can say "If John runs then he has fun;" but we could also say "If Francis thinks that if John runs then he has fun then he is relaxed." The phrase sounds complicated but certainly illustrates well this second capacity of having a dependence between words, which are, so to speak, "nested." Nesting can also repeat itself indefinitely, if limits external to the syntax do not halt it. And also this property is independent of the linear order: the nested structure is a typical hierarchical structure.

It is clear that relation at a distance and nesting do not exhaust all the properties of language – which is a universe in itself, like the world of physics – but they allow us to grasp in a rigorous way the intuition that human language consists of an "infinite use of finite means" (to use the famous words of Wilhelm von Humboldt). Going back to the question if animals speak, it comes at hand to paraphrase a famous answer given by Alan Turing after being asked if computers think: if you extend the concept of language in order to include all animals, then even the poppies chat between them.

4. The boundaries of Babel and the flesh: where do syntax rules come from?

The term syntax is very old: it was certainly used in a systematic way already at the time of Alexander, when many of the notions of grammar which have been thought at the first years of school since two millennia were first coined. Taking for granted that language depends on brain activity, the question is whether the rules and elements we call syntax are effectively represented as such in the brain, or are they rather an arbitrary taxonomy to describe lin-

guistic data in a coherent way? A priori this is impossible to answer. It is as if we asked how does digestion work without being able to see what is inside the abdomen.

Even if much data in favour of the biological hypothesis had origin already in medicine, the decisive turn came with the application of neuroimaging techniques. These are able to explore brain activity by measuring the blood flux, and allowed us to go beyond research based solely on clinical data and autopsy. It goes without saying that these machines, like any other, have limits: for example, it is very difficult to isolate a specific activity, given that the brain is always all active. Moreover, syntax is not even in a linguistic point of view an isolated phenomena: it is accompanied, by definition, by all the other mechanisms of language, starting from semantics.

A first experiment in favour of the hypothesis that there exists a dedicated neuronal activity which corresponds to the syntax was envisaged by constructing a number of kinds of errors (including syntactic ones) in a language without any semantic reference [9]. It was verified, for example, that when a person reads a phrase with words such as *"the glock gums the brails"*, if we compare the brain reaction to errors regarding syntax (e.g., "the glock gum the brails") with that to errors that violate syntax (e.g., "glock the gums brails the"), it is seen that the brain activates different regions, evidencing the existence of a specific network for syntax.

But using the neuroimaging technique we arrived also at giving strong proof of an still greater hypothesis: that the brain recognises as linguistically acceptable only a few of all the possible envisaged syntactic rules, and these are those specifically based in the hierarchical order, as opposed to the linear order [10]. The idea is simple: one constructs "impossible" rules (that is, based on linear principles) and sees how the brain reacts when using them. The result, repeated in multiple experiments, is that the brain sorts – so to speak – the different types of rules: the hierarchical ones activate the circuitry typical of the language, whereas those based in the linear order do not [11, 12]. The latter usually activate the circuits typical for the solution of problems of a non-linguistic nature [13].

Therefore, despite the appearances, the boundaries of Babel actually exist and are defined in our flesh; actually, they are direct expression of it. The properties singled out in the syntax of human languages are neither fruit of convention nor arbitrary. Appearance, in fact, is never a good counselor in science.

The felling is that as we progress on the research about the nature of human language, the questions never decrease. It is a bit like Achilles and the turtle. But we should be optimistic: altogether, based on much data, we can arrive at, if not grabbing our turtle, at least to looking it in the eye.

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