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The semantic theory of language

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ABSTRACT

Traditional linguistics was based on the idea that language is an activity that links *sounds and meaning*, an idea that has been referred to as '*the code view of language*' because codes are the most familiar processes that generate meaning. Ever since the work of Noam Chomsky, however, this view has been increasingly replaced by '*the syntax view of language*', the idea that children learn a language because they have an innate mechanism that allows them to grasp the syntax of whatever language they grow up with. This innate mechanism has been given various names – first *Universal Grammar*, then *Language Acquisition Device (LAD)*, and finally *Faculty of Language* – but despite decades of research attempts there still is no evidence that such a device actually exists. At the same time, it has become increasingly clear that codes are not the sole processes that generate meaning. Another such process is the ability of higher animals to *interpret* what goes on in the world, and interpretation is different from coding because it is not based on fixed rules but on a process that Charles Peirce called *abduction*. This allows us to generalize the *code view of language* into the *semantic view of language*, a theory which maintains that language is primarily a *semantic activity* that gives meaning to sounds either by codes or by processes of interpretation. This view, furthermore, gives us a new theoretical framework for studying the origin of language without resorting to any *deus ex machina* device. In this framework the origin of language is compared with the origin of life and the origin of mind, because those mega transitions generated the three great families of codes that we find in Nature – the organic codes, the neural codes and the cultural codes – and it is possible that a comparative study allows us to catch a glimpse of the mechanisms that gave origin to language.

1. Two different views of language

Ever since Aristotle language has been primarily regarded as an activity that links *sounds and meaning*, and requires therefore the co-ordination of two distinct systems: a phonetic system that receives and produces sounds (the *sensory-motor* component of language) and a cognitive system that gives meaning to sounds (the *semantic* component of language). At the same time, it was acknowledged that there is also a third important component in language, and that component is *syntax*, the set of rules that all combinations of sounds must follow in order to be accepted as valid linguistic expressions.

It goes without saying that all three components (phonetics, semantics and syntax) contributed to the origin of language, but most theories underline that one of them had a crucial role and propose models that are predominantly based on that component. Noam Chomsky, in particular, attributed the central role to syntax, and proposed what can be referred to as '*the syntax view of language*'.

Chomsky's most seminal idea is the concept that our ability to learn a language is *innate*, that children are born with a mechanism that allows them to learn whatever language they happen to grow up with (Chomsky, 1957, 1965, 1975, 1995, 2005). That inner mechanism has been given various names – first *Universal Grammar*, then *Language Acquisition Device (LAD)*, and finally *Faculty of Language* – but its basic feature remains its *innateness*. The mechanism must be innate because it allows children to master an extremely complex set of rules in a limited period of time and in a precise sequence of developmental stages. Chomsky, furthermore, maintained that syntax must be based on very general principles of economy and simplicity that are similar to the *Principle of Least Action* in physics or to the rules of the *Periodic Table* in chemistry (Baker, 2001; Boeckx, 2006).

A completely different view is that which attributes the crucial role to the semantic component of language, i.e., to its meaning generating activity. This has been referred to as '*the code view of language*' because codes are the quintessential processes that create meaning. In the Morse code, for example, the rule that 'dot-dash' corresponds to letter 'A', is equivalent to saying that letter 'A' is the meaning of 'dot-dash'. In the same way, the rule that a codon corresponds to a certain amino acid is equivalent to saying that amino acid is the *organic meaning* of that codon (Barbieri, 2003).

Codes, in short, are processes that generate meaning and if language is a system that gives meaning to sounds there must be codes in it. It has to be underlined, however, that codes are not a homogeneous class

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because there are three distinct types of codes in the world, so let us take a brief look at them.

2. Three types of codes

All living organisms contain a virtually universal genetic code and this means that code evolved in a population of primitive systems that is collectively known as the *common ancestor*. The genetic code, on the other hand, was followed by many other *organic codes* in the first three thousand million years of the history of life, when our planet was exclusively inhabited by microorganisms (Barbieri, 2003). Among them, the *sequence codes* (Trifonov 1989, 1996, 1999), the *histone code* (Strahl and Allis, 2000; Turner, 2000, 2007; Kühn and Hofmeyr, 2014), the *splicing codes* (Barbieri, 2003; Fu, 2004; Wang and Cooper, 2007), the *signal transduction codes* (Barbieri, 2003), the *compartment codes* (Barbieri, 2003), the *tubulin code* (Verhey and Gaertig, 2007; Janke, 2014), the *ubiquitin code* (Komander and Rape, 2012), the *molecular codes* (De Beule et al., 2011; Görlich et al., 2011; Görlich and Dittrich, 2013; Dittrich, 2018) and the *lamin code* (Maraldi, 2018).

With the origin of animals, about 600 million years ago, a second type of codes appeared on Earth, codes that are referred to as *neural codes* because they are rules between neural states. The organic codes are rules between organic molecules and these are *space-objects* in the sense that their characteristics are due to their three-dimensional arrangement in space, whereas the neural codes are rules between neural states and these are *time-objects* in the sense that they are caused by fleeting sequences of action potentials and neuron firings in time.

The neural codes are much more difficult to study than the organic codes, but some of them have already been discovered; the Nobel Prize for Medicine in 2014, for example, was awarded to John O'Keefe, May-Britt Moser and Edvard Moser for the discovery that the cells of the hippocampus use the rules of a neural code to build an internal map of the environment (O'Keefe and Burgess, 2005; Hafting et al., 2005; Brandon and Hasselmo, 2009). Other examples are *the neural code for mechanical stimuli* (Nicolelis and Ribeiro, 2006; Nicolelis, 2011), *the neural code for taste* (Di Lorenzo, 2000; Hallock and Di Lorenzo, 2006), *the olfactory code* (Grabe and Sachse, 2018) and the *acoustic codes* (Farina and Pieretti, 2014; Farina, 2018).

Finally, the evolution of man gave origin to a third type of codes that are collectively known as *cultural codes*. The laws of government, the precepts of religion, the value of money, the rules of chess, the highway code and countless other conventions are all codes that make up the world of human culture.

The existence of so many different codes in living systems makes us realize that nature resorted to the mechanism of coding time and time again in the history of life, and it would not be surprising therefore if codes were also involved in the origin of language. Things, however, have turned out more complex than that because it has been found that higher animals have evolved an additional mechanism that allows them to give meaning to what goes on in the world.

3. Two semantic mechanisms

Animals can give meaning to the signals from the environment with neural codes, but some of them have also evolved means of *interpreting* what goes on around them. The difference between codes and interpretation is beautifully illustrated by a classical example of animal behavior. When a snake chases a prey and the prey disappears from sight, the snake *stops* chasing. When a wolf chases a prey and the prey disappears from sight, the wolf *goes on* chasing. The snake is only using *codified rules*, whereas the wolf makes an act of *interpretation*. The wolf makes a 'mental jump beyond the appearances', and that is what interpretation is (Shettleworth, 2010).

The brain, furthermore, has the ability to form memories, and a set of memories is the basis of learning because it allows an animal to decide how to behave in any given situation by comparing the memories of what happened in previous situations. A set of memories, in short, amounts to a model of the world that is continuously updated and that allows an organism to *interpret* what goes on around it.

Any animal, on the other hand, can only cope with a limited number of memories whereas the real world offers a virtually unlimited number of possibilities. Clearly, a model based on a finite set of memories cannot be perfect, but it has been shown that neural networks can in part overcome this limit by interpolating between discreet memories (Kohonen, 1984; Siegelmann, 1999). In a way, they are able to 'jump-to-conclusions' from a limited number of experiences, and in most cases these 'guesses' turn out to be good enough for survival purposes.

This *extrapolation from limited data* is an operation that is not reducible to the classical Aristotelian categories of *induction* and *deduction*, and for this reason Charles Peirce (1906) called it *abduction*. It is a new logical category, and the ability to interpret the world appears to be based on that logic.

Interpretation, on the other hand, is a form of semiosis because it gives meaning to something, but it is different from coding because it is based on abduction and not on fixed rules.

Animals, in conclusion, have evolved two different ways of producing meaning – neural codes and processes of interpretation – and we need therefore a theoretical framework that takes both of them into account, a framework that here is referred to as '*the semantic theory of language*'.

The experimental evidence, furthermore, has brought to light not only the existence of processes of interpretation in higher animals, but also the fact that the biological codes (organic codes and neural codes) are profoundly different from the codes of culture, and this is something that we must account for.

4. The adaptors of language

The genetic code appeared almost four billion years ago in the common ancestor of all living systems and it has been highly conserved ever since. The first neural codes (the rules by which the animal sense organs transform the incoming signals into neural states) appeared almost 600 million years ago in the common ancestor of all animals and have been highly conserved ever since. The cultural codes produced by man, on the other hand, are continuously changing, and this gives us a major problem: why are they so different from the biological codes?

In order to deal with this problem, let us start from the fact that the rules of a code are implemented by structures called *adaptors* and that a code emerges from the evolution of its adaptors. The adaptors of the genetic code, for example, are the transfer-RNAs, and it was the evolution of these molecules that gave origin to the rules of the modern genetic code (Barbieri, 2015). The adaptors of the neural codes are the neurons of the intermediate brain, and it was the evolution of these cells by processes of embryonic differentiation that gave origin to the rules of the modern neural codes (Barbieri, 2019). In the biological codes, in other words, (1) the adaptors are the structures that physically implement the coding rules and (2) the conservation of a code is due to the conservation of its adaptors.

In language, however, the situation is different. Language does have signs and meanings, and therefore it has adaptors because these are the intermediaries between signs and meanings, but the adaptors of language are different from the adaptors of the biological codes. This is because a human child learns whatever language is presented to him or her, and that experimental fact means that the rules of language *come from outside the child not from inside*. They come from the community in which the child is born, and the adaptors that exist in a child have the purpose to *acquire* the rules of language, not to generate them.

This gives us the first hypothesis of the semantic theory of language: '*the adaptors of language do not generate the rules of language, they merely allow children to interpret those rules*.'

Another experimental fact is that different human societies have evolved different languages and are in a constant state of change, all of which gives us the second hypothesis of the semantic theory: '*the cultural codes change because their rules are produced by societies that continuously change; the biological codes do not change because their rules are produced by adaptors that are highly conserved in evolution*.'

According to the semantic theory, in other words, the adaptors of language are the neural networks capable of abduction that allow children to learn a language by *interpreting* the sounds that they encounter in the first years after birth. These neural networks, on the other hand, exist in countless other animals (Shettleworth, 2010) and this gives us a massive problem: why did language evolve only in our species?

The answer of the syntax view of language, as we have seen, is that only man has a special '*language acquisition device*' but in reality there is no experimental evidence that such a device exists. What we do have, instead, is ample evidence that in our species there is a unique type of fetal development, and according to the semantic theory, as we will see, this singularity has a lot to do with the origin of language.

5. A unique form of development

In the 1940s, Adolf Portmann pointed out that our species has a unique type of development. In all other animals, development is either predominantly *altricial* (if the young are born helpless) or predominantly *precocial* (if they can cope with the environment) but in our species it is a combination of both types, and for this reason Portmann put it in a category of its own and called it *secondarily altricial*. More precisely, human development has the precocial features of all other primates combined with a massive acquisition of altricial features that makes a human baby at birth look totally helpless. Portmann, furthermore, calculated that humans should have a gestation period of 21 months in order to complete all processes of fetal development that the other primates have already attained at birth (Portmann, 1941, 1945). A newborn human baby, in other words, is a premature fetus, and the entire first year of human life is dedicated to completing the processes of fetal development.

This peculiarity was probably due to an evolutionary tendency to prolong the duration of development together with the constraint that the birth canal can only cope with a limited increase of fetal size. This means that any extension of the fetal period had to be accompanied by an anticipation of the time of birth (Dunsworth, 2016). The result was that our fetal development became divided into two distinct phases – intrauterine and extrauterine – and eventually the extrauterine phase (12 months) came to be the longest of the two. It is not clear why this type of development evolved only in our species, but it is a fact that in all other primates fetal development is completed *in utero*, and a newborn is no longer a *fetus* but a fully developed *infant* that is already capable of fending for himself.

The crucial point is that fetal development is a period of intense *brain wiring* and its extrauterine extension has produced a truly unique situation. In all other primates the fetal wiring of the brain takes place in the dark and protected environment of the uterus, whereas in our species it takes place predominantly outside the uterus, where the body is exposed to the lights, the sounds and the turbulences of a constantly changing environment (Barbieri, 2010).

Another important information about human development has come from the discovery that children raised in conditions of extreme isolation or raised in the wild by animals (the so-called *feral children*) have a highly reduced potential to learn a language (Maslon, 1972; Shattuck, 1981; Pinker, 2007). This has shown that the acquisition of language is *not* a spontaneous process and takes place in a normal way only if the postnatal development of a child is *actively assisted* by other human beings.

This gives us the third hypothesis of the semantic theory: '*language evolved exclusively in our species because only human beings go through an extremely long period of extrauterine fetal development, and it is an experimental fact that what happens in this period is crucial to the acquisition of language*.'

6. A unique modelling system

A human child is born when his fetal development is less than halfway through, a situation in which he can barely move his body and is practically helpless. Emitting sounds is virtually the only way of getting attention and soon he or she starts making connections between emitting and receiving sounds. This sets in motion what Cowley (2007) has described as a prolonged sequence of back-and-forth interactions between mother and child where they continuously regulate their responses and adapt to each other.

These interactions have the typical trial-and-error patterns of the interpretive processes, and this strongly suggests that they are realized by interpretive neural networks, i.e., by networks that are capable of abductions. Interpreting sounds, on the other hand, means making abductions that associate sounds with a variety of mental states, including those that represent objects.

A human child learns in this way to form the mental image of an object not only when the object is present, but also when he hears the *name* of the object. Names have nothing to do with objects, and an abduction from names is an *abduction from symbols*. In all other primates, the neural networks are predominantly used to make abductions from objects, not from symbols, because they rarely encounter situations in which they have to use symbols as substitutes for real objects.

Human children too have inherited the ability of interpreting what goes on among the objects of the physical world, and this animal modelling system does not interfere with the interpretation of symbols because the brain is used to process different neural states in parallel, as shown by the fact that the processing of sound is independent from the processing of light or from the processing of temperature.

Human children develop in this way two distinct modelling systems, one for the world of nature and one for the world of culture, and this gives us the fourth hypothesis of the semantic theory: '*language is a modelling system that makes a massive use of symbols and this makes it fundamentally different from all other animal communication systems*.'

The semantic theory, in conclusion, accounts for the origin of language with hypotheses that are based on what we actually observe in Nature and not on *ad hoc* devices. It tells us that the rules of language are generated by human societies, not by individual human beings, and that they are acquired by children with interpretive neural networks that we have inherited from our animal ancestors.

7. A sister theory on evolution

It is rare that the same name is given to theories that deal with different problems but in our case this has happened. A long time ago I proposed *The Semantic Theory of Evolution* (Barbieri, 1985) and the term *Semantic* was used exactly in the same sense as in *The Semantic Theory of language*. In both cases the purpose was to show that there is a semantic mechanism at work in living systems. There is therefore a link between the two theories, so let us take a brief look at the first of them.

The discovery that heredity is transmitted by genetic sequences implies that *information* exists in all cells, and the discovery that protein synthesis takes place according to the rules of the genetic code implies that *meaning* exists at the cellular level.

The concept of meaning, however, was not introduced in biology on the basis of two main arguments. The first was the conclusion of the *Stereochemical Theory* that the genetic code is not a real code because its rules were determined by chemistry and do not have the arbitrariness that is the sine *qua non* feature of all real codes. The second was the idea that the cell is a biological computer made of genotype and phenotype (software and hardware) and a computer is not a semantic system because its codes come from an external operator, and not from an internal agent.

The first argument has been proved wrong by the experimental demonstration that any codon can be associated with any amino acid (Schimmel, 1987; Hou and Schimmel, 1988; Schimmel et al., 1993), which means that there are no deterministic links between them. It is an experimental fact, in other words, that the genetic code is based on arbitrary rules and is therefore a real code that generates real meaning.

The second argument has been proved wrong by the demonstration that the cell does contain an internal agent that generates the rules of the genetic code, and this implies that biology needs a completely new model of the cell.

The first goal of the semantic theory was exactly the description of that new model; more precisely it was the idea that the cell in not a duality of genotype and phenotype but a trinity of *genotype, phenotype and ribotype*, where the ribotype is the ribonucleoprotein system that makes proteins according to the rules of the genetic code, and is therefore the *codemaker* of the cell, the internal agent that makes of the cell a true semantic system.

The second goal of the semantic theory was the idea that the genetic code cannot be the sole organic code that exists in Nature because in this case it would be an extraordinary exception and not a normal component of life. This idea was expressed by saying that copying and coding are the two fundamental processes of life, and that evolution took place by natural selection (based on copying) and *by natural conventions* (based on coding).

In 1985 there was no evidence of other organic codes in living systems, but a few years later that evidence started accumulating and today we know not only that many organic codes appeared in the history of life but also that their appearance went hand in hand with the great events of macroevolution. As a result, the study of the organic codes has become a new field of research, and the semantic theory of evolution has been replaced by *Code Biology*, the scientific study of all codes of life.

This gives us something to look forward to. To the possibility that the semantic theory of language is also followed by discoveries and turns, like its sister theory, into a new field of scientific research.

Declaration of competing interest

There is no conflict of interest.

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