# A closer look at the turtle's eyes

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There are works in science that become important not only for the relevance of the empirical and theoretical findings they originally provide but also because they come at a special moment and help the scientific community to disentangle the debate when things start to get involuted and research paths tend to go in circles. The work presented by Pallier et al. in PNAS (1) certainly meets this special requirement: quantitative neuropsychological data are offered to support the hypothesis that words are combined into hierarchical structures (i.e., constituents) rather than being linearly organized. To arrive at such a conclusion, the authors provide evidence that a set of brain regions responds monotonically to the hierarchical constituent structure of sentences, thus shedding light on the cortical implementation of a central aspect of language, arguably the one marking the watershed between human and nonhuman communication codes (2). The burden of proof against a hierarchical view of syntax becomes very heavy from now on.

### The Logical Premise to Neuropsychological Discoveries

Of course, no phenomenon in nature belongs to any academic domain, but when it comes to language things may be less obvious: certain disciplines tend not to look at the results achieved by others, prototypically linguistics, neuropsychology, and information theory. The effect is that sometimes some central results must be explicitly recalled as if they had not been completely assimilated, not to say "forgotten." It cannot be a coincidence or a rhetorical trick that in such an advanced article as the one presented here the authors felt the necessity to cite the first book by Noam Chomsky, published in the late 1950s (3). For all who read it, the fact that this book is referred to is hardly surprising, for at least the two following reasons: the kind of results that were offered there had the epistemological status of theorems and proved that natural language could not be described as markovian chains—that is, fundamentally, as flat structures solely organized by statistic transitions—but they had to incorporate the notion of recursion in a crucial way. To put it simply, a recursive procedure in a linguistic sense is one where a structure of a *certain* type can be contained in a structure of the *same* type. So, for example, a sentence can be contained in a sentence as in [[*that Dante loves Beatrice*] *is surprising*]. Of course, recursion can be potentially iterated ad infinitum, pace extragrammatical restrictions on parsing and memory limits. After more than 50 years, clearly, this work [and the enormous amount of research it yielded (4, 5)] cannot be ignored and can be considered the precursor to the new wave of studies on the relationship between language and the brain. The landmark results presented by Pallier et al. (1) can also be thought of as a way to give new force to the basic tenets of generative grammar expressed in that original book: if constituent structures were descriptive artifacts, the different response of brain structures would at best be a surprising coincidence.

**Recursion makes such a thing as rigid dependency impossible in natural languages.**

### Syntax in the Brain or the Discovery of "Impossible" Rules

Nevertheless, as with all interesting experiments, the one presented here opens new empirical and theoretical questions. There are at least three conceptually distinct issues to be considered. The first concerns the way these results fit with the independent discoveries made in the field. The second, instead, is rather a question of what kind of experimental paths we may expect in the future by relying on this type of result. The third bears on some recent attempts at reducing language structure to other (cognitive) capacities: certainly not a new effort but one based on allegedly new empirical reasons. The article by Pallier et al. (1) offers a unique opportunity to reflect on all these issues.

Let me start with the convergence of the Pallier et al. (1) results with independent findings in neurolinguistics. Convergence is hardly a marginal aspect within such a fragmentary field of research. Are there other results that support this view of syntax? The key step comes from focusing on the notion of hierarchy, with a logical premise: constituent structure is hierarchical, but the hierarchy is of a special type —it comes from recursion. In fact, not all hierarchical objects are recursive. Just to stick to language structure, syllables arguably have a hierarchical architecture but certainly not a recursive one (6). Now, recursion has several interesting effects on language structure: it provides a formal mechanism to capture the fact that sentences do not have an upper bound length limit (much as there is no such thing as the biggest number, there is no such thing as the longest sentence) and, crucially, it makes it impossible for a syntactic rule affecting two (or more) words to be based on the position of the words in the linear sequence where they occur; call these conceivable rules "rigid dependencies." In fact, because by definition one could always recursively insert new material between two dependent words, their relative position in the sequence can indefinitely change, and it becomes irrelevant; in other words, recursion makes such a thing as rigid dependency impossible in natural languages. At least four different works in neurosyntax [three of them cited in the work (7–9), plus another (10)] provide evidence that syntactic dependencies based on recursive structures, such as for example agreement, correlate with a dedicated set of brain activations (crucially distinct from those correlated with rigid dependencies). As a consequence, the very fact that both dependency and constituency, as shown in the article by Pallier et al. (1), can be independently proved to be related to dedicated neural activities is thus per se an extremely interesting result that mutually reinforces the neurolinguistics hypotheses underlying them.

The second issue is rather linked to theoretical linguistic considerations. The title of the article by Pallier et al. (1) refers to the "constituent structure of sentences," but there is a certain ambiguity in this phrase. Showing evidence in favor of the fact that sentences are organized in constituents [which is what Pallier et al. (1) elegantly do] is different from individuating whether constituents have any internal nontrivial structure. In fact, to provide a positive piece of evidence in favor of the latter much stronger hypothesis one should prove that the building blocks making the constituents correlate differently with respect to neural activities. An experiment on code switching has in fact supported such a stronger conclusion

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(11). Subjects were exposed to two distinct types of switches depending on the position within the constituent where the switch occurred. In one case the switch took place between the specifier and the head of the constituent (for example, between *these* and *books* in *these books about God*); in the other, instead, between the head of the constituent and the complement of the head (for example, between *books* and *about God* in the same constituent). Crucially, the result was that the neurological nets involved in detecting the two distinct types of switches were different. More specifically, and interestingly, only when the switch took place between the specifier and the head did it involve neural networks that are normally involved in morphosyntactic phenomena. A prototypical morphosyntactic phenomenon is in fact agreement: it occurs between the specifier and the head, not between the head and the complement (as in *the-se book-s*, which must both be plural). If we now combine this result on constituent structure based on code switching with the result obtained by Pallier et al. (1) based on the amount of material involved, we get at least two consequences. First, the combination of these results suggests that the quantitative methods adopted to provide evidence that there exist constituents could be extended to explore the internal structure of the constituents themselves. For example, the authors test the interpretation of *'s* genitive marked modifiers as in [*Mary's* [*hat*]]; it could be very interesting to determine whether one gets similar results in case of nongenitive marked modifiers, that is nonmorphologically marked modifiers, such as a [*City* [*Hall*]] or [*sales* [*director*]]. Second, they further suggest that morphology is a crucial variable to manipulate if one wants to explore the internal structure of constituents by means of the same quantitative strategy as the one used by Pallier et al. (1). In fact, this could offer a complementary perspective along with the strategy of confronting fully lexical roots vs. pseudowords that Pallier et al. (1) adopted.

Finally, there is another consequence of this experiment that should be highlighted, although it does not just refer to this specific result. There is a general contemporary tendency to suggest that the structure of human languages, evolutionarily speaking, is a sort of emancipation from sophisticated motor control capacities (12). Although it is certainly true that there are aspects of language that may have embodied nonlinguistic capacities—such as in the case of action verb interpretation (13)—it seems to me that it is also true that crucial architectural factors like recursion cannot be derived at all from any other (cognitive) capacity or "external" property of the real world (as perceived by our mind/brain) in the broad sense. Such neoreductionist attempts, which in fact, at least historically, have always surfaced in linguistic thought as in the case of the Modists (14), find in results such as the one offered in this article what seems to me to be an insurmountable obstacle. How could recursive constituent structure be traced back to extralinguistic capacities? Rather, constituent structure, as well as other case studies, such as negation for example (15), offers a unique opportunity in favor of the hypothesis that the core aspects of language structure cannot be derived from (our reactions to the) structures of the external word either directly or indirectly as emancipation of other capacities.

## A Realistic Optimism

Less than 50 years ago, Eric Lenneberg (16) wrote, "A biological investigation into language must seem paradoxical as it is so widely assumed that languages consist of arbitrary, cultural conventions." Works such as the one presented here by Pallier et al. (1) certainly contribute to making such a worry anachronistic. Nevertheless, although I am completely sympathetic and convinced by this study's results and methods, I would rather not totally adhere to the optimistic spirit it ends with: "Finally, equivalent studies using finer temporal methods such as magnetoencephalography should provide detailed information as to the time course of constituent formation, ultimately paving the way to a detailed understanding of the neural code for syntax." I do rather belong among those who think that our species will never be able to reach the totality of what is known as language—syntax, in particular—or, even more radically, that we will actually have to give up the idea of language as a unitary neurobiological object and rather think of it as partially created by our cognitive system as a whole; much like the Kanizsa triangle, its unitary nature could well be made up by our brain, but it is not really there: it is a cognitive mirage (17).

Like Achilles with the turtle, whenever we get closer to language structure our object of inquiry seems to get a little farther away. Nevertheless, it is because of studies like the one presented by Pallier et al. (1) and all those they cite in their article that even if we may not ultimately put our hands on our turtle, at least we will get so close as to get a direct look into its eyes.


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