On the similarity between syntax and actions.

Abstract: One of the major discoveries in the history of XX century linguistics is that the linear sequence of words constituting a sentence is organized in a hierarchical and recursive fashion. Is this hierarchical structure similar to action and motor planning, as recent proposals suggest? Some crucial differences are highlighted on both the theoretical and empirical ground that make this parallel empirically and theoretically unsuitable with far-reaching consequences on evolutionary perspectives.

An apparent similarity between language and actions.

One of the major discoveries in the history of XX century linguistics is that the linear sequences of words (the lexicon) is organized in a hierarchical fashion by a simple binary recursive computational operation merging lexical items (technically referred to as "Merge"). Is this architecture specific to human language structure or are there analogous patterns in other cognitive domains? The answer to this question has very far-reaching consequences, including the way we may search for evolutionary clues concerning the human mind.

The search for the neuropsychological networks underlying this architecture is of course one of the major empirical and theoretical challenges of contemporary neuroscience. Recent works have paved the way toward this goal [1, 2] but some major issues still need to be clarified [3, 4, 5]. Moreover, not all hierarchical structures are *necessarily* recursive in human language, such as for example the syllable structure, making syntax special with respect to other modules of grammar. Notably, it is such hierarchical architecture that matters for any syntactic relation not the linear order, which is just an epiphenomenon due to

both computational, formal and neuroanatomical reasons [6, 7, 8] : among them, "nested dependencies". A typical example at the word level is the *either/or*, the *if/then* dependency but dependencies can typically occur even below the word level as in the ubiquitous case of agreement morphemes. Concentrating on words, whenever a word like *either* enters the computation a dependency is established with *or* in two points of the hierarchy, hence of the linear sequence; analogous dependencies can be nested *ad infinitum*, provided that memory load and parsing restrictions do not intervene to block it, as in the following example where "A" and "B" mark the correlated elements: [*either*$_A$ *someone told you that* [*either*$_B$ *you go to Rome or*$_B$ *you will be arrested*] *or*$_A$ *you are a fool to go there*].

Recently, the hypothesis has been addressed that "basic body acts are joined in action chains to form a meaningful goal-directed action sequence" and that "the hierarchical structure of embedded or 'nested' sentences is paralleled (by them)" [9]; in other words, *mutatis mutandis*, the sequence of actions represented as "[open the door [switch the light] close the door]" would parallel the former type of syntactic dependence established in *either/or* sentences suggesting that actions are organized on the same architectural model as the syntax of human language. Is this analogy between language and actions true or, at least, useful? The implications of this hypothesis are very far reaching since they obviously also bear on evolutionary considerations.

Actions take place in the physical world and are subject to its physical restrictions (particle interactions, anatomical structures, etc.); syntax on the other hand, is essentially a mind/brain phenomenon (the physical condition being relevant only insofar as the brain is itself a physical object, of course). Certainly, actions can be organized hierarchically as can be the branches and leaves on a tree. But syntax does not only consist of a lexicon and Merge, it also crucially includes a filter limiting the number of successful combinations yielded by Merge, technically called (principles of) "Locality". Is the "syntax of actions" meeting these

three requirements? The analogy between syntax and actions must accordingly be checked against the notion of "word" and Locality to test if it is empirically tenable. Let us first consider the notion of "word".

Does the notion of "word" apply to actions?

Relying on studies on the macaque monkey, the proposal has been made that there indeed exist a "motor vocabulary" [10]: "This motor vocabulary is constituted of "words," [...] These words select specific "motor prototypes" such as, for example, the configuration of fingers necessary for the precision grip". There can be hardly any doubt that the idea of a set of "preformed motor prototypes" is very appealing. Is it also true when compared to the structure of human language?

One of the universal properties of human languages is that the lexicon can be parted into two classes: an unbounded set of words carrying the meaning of objects, actions, qualities, feelings, etc. and a small and fixed repertoire of "functional" words containing "logical" and set-theoretical instructions (such as *the*, *if* or *not*). If there are no pathologies, such as in agrammatism, the burden of information is practically equally distributed between these two classes in each and every sentence. If the "motor vocabulary" is constituted of "motor prototypes" then there is no hope to have anything equivalent to functional words in the vocabulary of actions. Of course, we do exploit functional words to *describe* a motor action verbally, as in *open your hand if you want to grasp the knife*, but this would just take us back to the structure of language. At the level of the lexicon, then, the analogy between language and actions seems not to be fully suitable. However, the most problematic aspect for the analogy between the syntax of words and actions comes from the notion of syntactic dependency.

Syntax contains a filter based on hierarchy: can there be one for actions?

A recalcitrant puzzle of human language stems from the contrast between the fact that there is no upper limit to the length of a sentence due to recursive procedures and the fact that the successful combination of lexical items appears to be strictly limited across languages by Locality conditions [11, 12]. Typical examples of these limits affect the so-called "displacement", an ubiquitous phenomenon that has been recognized since the first decade of the last century. A prototypical case is question formation in English where the dependency between, say, a verb and its object may be established even if the two are not adjacent. So for example, the dependency between *a book* and *read* in a complex sentence like [*Peter thinks* [*that Mary read a book*]] is the same as in [*which book does Peter know* [*that Mary read*]]*?* despite the fact that the closer potential verb on which *book* could depend is *know*, witness sentences like *they know a book?.* How does Locality restrict displacement? Consider for example the following two sentences: [[*Peter saw Mary reading a book*] [*before writing the essay*]] and [[*Peter saw Mary writing the* essay] [*before reading a book*]]. Surprisingly, the dependency between *reading* and *book* can be established only in the first sentence after displacement takes place: [[*which book did Peter see Mary reading*] [*before writing the essay*]]*?* vs. * [[*Which book did Peter see Mary writing the essay*] [*before reading*]]*?* Memory buffer based solutions to these types of contrasts fail, witness the possibility to establish dependencies at a longer distance in sentences like [*which book does John think* [*my father's blond sister believed* [*Peter saw* [*Mary reading*]]]*?* .

Locality has been at the very center of theoretical syntax since it was first discovered and is recognized as a core and definitory component of syntax massively reducing the amount of computation: in no human language can Locality be absent. What matters here is that this filter is "purely geometrical" in the sense that it is based on the hierarchical relations resulting from Merge. The explanation of the contrast under discussion here, for example, is based on the fact that in the ungrammatical case the sentence containing the verb *reading* is

merged after the first one is already fully assembled, as indicated by the brackets . In fact, both Locality and displacement can be (partially) derived as a consequence of Merge, if a Dynamic Antisymmetry approach to movement is adopted [7, 8] Now, going back to the original claim that a sequence of actions verbally expressed like "[open the door [switch the light] close the door]" is governed by the same principle as syntax, we realize that unless some Locality principles are found that are based on the alleged hierarchical and recursive structure connecting actions, no parallelism can be inferred. This is in fact a completely open question and a challenging one. No commitment appears empirically and theoretically legitimate unless this preliminary fact has been clarified.

Nothing more than an (appealing) metaphor.

Could the operation of Merge be generalized to intentions and motor planning actions yielding the same rich set of complex hierarchical recursive structures and could Locality conditions based on them be observed in this realm as well, then the analogy between syntax and the domain of actions may become more than a metaphor and one can start exploring the possibility of finding a precursor to the basic operation of composition yielding all properties characterizing human syntax.

The failure of this analogy however can be regarded as a welcome fact. If motor actions were the phylogenetic and ontogenetic precursor of human language [13] the singularity of this code across species, and most crucially with respect to monkeys, would be a much harder mystery to solve [14, 15] especially since the specific format of human syntax has been definitely anchored to the neurobiological structure of the brain [1, 2, 14].

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Author's address: Prof. Andrea Moro, Institute of Advanced Study IUSS Pavia, Piazza Vittoria 15, 27100 Pavia, Italy

Corresponding author: andrea moro (andrea.moro@iusspavia.it)