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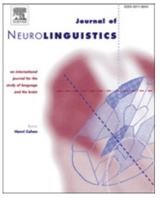

Core linguistic computations: How are they expressed in the mind/brain?

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A R T I C L E   I N F O

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A B S T R A C T

Over the last half century, linguists have introduced very detailed formal models of language knowledge, acquisition and use, and have proposed refined typologies of the kinds of mental computations involved in language. These models, in turn, capture and systematize observations and ideas developed in centuries of rational reflections on language. It is in the mutual interest of both linguists and cognitive neuroscientists to bridge the gap between mind and brain in this domain, and make substantial progress in connecting abstract models of linguistic competence and performance, and the study of the neural implementation of the computing mechanisms.

In this paper I would like to offer a concise tutorial on some core ideas and analytic devices introduced in formal linguistics to deal with linguistic computations and language variation, with special reference to parametric and minimalist models. Then, I would like to conclude by phrasing some questions that current ideas on mental linguistic computations raise for the brain sciences.

1. Introduction

Over the last half century, linguists have introduced very detailed formal models of language knowledge, acquisition and use, and have proposed refined typologies of the kinds of mental computations involved in language. These models, in turn, capture and systematize observations and ideas developed in centuries of rational reflections on language. It is in the mutual interest of both linguists and cognitive neuroscientists to bridge the gap between mind and brain in this domain, and make substantial progress in connecting abstract models of linguistic competence and performance, and the study of the neural implementation of the computing mechanisms.

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On the one hand, linguistic models typically involve a detailed internal articulation of components which perform distinct computations. It is reasonable to make the hypothesis that this articulation is expressed in the organization of the neural circuitry. The brain sciences can therefore expect from theoretical linguistics a generator of hypotheses on the different kinds of mental computations for language, to be used in the attempt to build spatial and temporal maps of the organization and functioning of the neural circuits performing such computations.

Conversely, linguistics can expect a broadening of its empirical basis with new types of empirical evidence. One can imagine types of neuro-imaging evidence contributing with other types of evidence (data from comparative linguistics, metalinguistic judgments, behavioral experiments, data from acquisition, aspects of pathology, etc.) to the choice between alternative hypotheses on the organization and internal articulation of language. Evidence from the neural implementation may put decisive empirical constraints to narrow down the vast class of formal models compatible with linguistic data.

In this paper I would like to offer a concise tutorial on some core ideas and analytic devices introduced in formal linguistics to deal with linguistic computations and language variation, with special reference to parametric and minimalist models. Then, I would like to conclude by phrasing some questions that current ideas on mental linguistic computations raise for the brain sciences.

2. The unbounded scope of the language faculty: inventories and computations

When we use our native language to communicate with others, we are constantly confronted with new sentences, sentences that we have never encountered in our previous linguistic experience, and which we can understand and integrate without any problem. Similarly for production: we constantly produce sentences that we have never heard before. In fact, our knowledge of language gives us mastery over a potential infinity of sentences, only a tiny fraction of which we have heard in our previous linguistic experience. What is this familiarity of the newness, sometimes also called “creativity in normal language use”? and how can we characterize the unbounded scope of our language faculty?

The first important contribution that Chomsky gave to the study of the language faculty was to identify a formal mechanism to tackle these questions (Chomsky, 1957). One can think of our knowledge of language as a computing device able to generate, and make available for use, a potential infinity of sentences. This mental grammar consist of two kinds of entities: **inventories**, lists of elements stored in memory which are the building blocks of computations; and **computational rules**, which put together elements of the inventories to form entities of a higher order. The lexicon is the fundamental inventory; in fact, the lexicon itself has a structure which is amenable to a modelling in terms of inventories and computations: phonemes are strung together according to certain rules to form higher order entities: syllables, and morphemes; morphemes are assembled to form complex words; words are strung together in rule-governed manners to form phrases and sentences. The “syntax” of phonology and morphology yields a finite number of combinations, syllables, morphemes, words; but syntax proper is unbounded in scope. Chomsky’s idea was that syntax is based on recursive mechanisms, rules which can indefinitely apply to their own output. For instance, a nominal can be modified by a relative clause, which can contain a nominal, which can in turn be modified by a relative clause, and so on:

(1) This is the man who wrote the article which worries the politicians who approved the bill….

Both concepts of inventories and computations have been the focus of intensive research over the last half century. As for the inventories, a classical distinction is between the **contentive lexicon** and the **functional lexicon**; the contentive lexicon consists of items with descriptive content, nouns, verbs, adjectives,… (Baker, 2003), referring to events (actions, states) and the persons or things participating in them; the functional lexicon consists of elements with more abstract interpretive properties (tense, definiteness, declarative or interrogative force,…) and providing the grammatical glue to hold together contentive elements: determiners, auxiliaries, copulas, tense and aspect markers, complementizers, etc. Sometimes, functional elements express a purely formal property or relation, and have no obvious interpretive content, e.g. non-referential pronouns (*it* in *it is raining*), or agreement markers. The distinction between contentive and functional lexicon is a traditional one, also echoing analogous distinctions like the one between open and closed class items. The exact boundary between the contentive and functional lexicon is clear in some cases, controversial in others, but the need for the distinction appears to be well-established (see Cinque & Rizzi, 2010 for recent discussion).

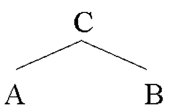
The respective role of the two lexicons in syntax has been significantly reconsidered in recent years. A clear recent trend has been the progressive emphasis put on the functional lexicon, which is now seen as playing a critical syntactic role in many respects:

– On the one hand, functional elements don't just provide marginal accompanying specifications to the core contentive elements: there is a real division of labor in which functional elements have an architectural role in the structuring of the sentence with the creation of configurational skeleta, a formal backbone for the insertion of contentive elements, which provide the descriptive content;
– more specifically, functional elements trigger the fundamental computational processes of Merge, Search and Move (on which see below), hence they are the locus of much of the syntactic action;
– they express basic syntactic parameters, hence they are the main locus of cross-linguistic variation in syntax;
– they give rise to very complex configurations, which are studied in "cartographic" projects trying to draw maps as accurate and realistic as possible of the syntactic structures (Belletti, 2004; Cinque, 1999, 2002; Rizzi, 1997, 2004, etc).

The study of computations also underwent a significant shift, from concrete, construction-oriented rules (e.g., transformations "dedicated" to particular constructions: relative formation, question formation, the passive transformation,…) to more abstract and elementary computational ingredients, such as Merge, Search and Move (Chomsky, 1981, 1995). Grammatical constructions still exist as descriptive entities, but they are viewed as conglomerates of properties to be factored into more elementary and abstract ingredients, interacting with triggers in the functional lexicon. For instance, a "relative construction" is defined by a certain type of complementizer, an element of the functional lexicon (*that* in English, or its null variant), plus a movement operation triggered by the crucial functional head; the "passive construction" is defined by certain dedicated functional elements (an auxiliary or an affix) plus different kinds of movement operations (Collins, 2005). Let us concentrate in what follows on the major elementary computational ingredients.

3. Merge as the fundamental structure-building rule

Much discussion has been devoted over the last half century to pin down the exact nature of recursion in human language. The recent proposal of the Minimalist Program (Chomsky, 1995 and much subsequent work) is that recursion is implemented in the simplest way one can think of. According to Minimalism, the fundamental structure-building operation of natural language syntax is Merge, which functions as follows:

(2) … A … B … ➔ 

The operation takes two elements A and B, for instance two lexical items (*meet, Mary*) and strings them together to form the unit [AB], for instance the phrase *[meet Mary]*. The new unit has a label, which is inherited from one of the merged elements: so in (2) C = A, or C = B. In general, Merge strings together two elements when one selects the other, and the element which projects (assigns the label to the whole structure) is the selector. The selector is also called the **head** of the construction. So, if the elements are *meet* and *Mary*, the unit formed *[meet Mary]* is a verb phrase, a projection of the verb, the element which selects the noun (a transitive verb selects a nominal direct object) and heads the construction. The unit which is created can in turn undergo Merge: for instance the verb phrase *[meet Mary]* can be merged with a tense marker drawn from the functional lexicon, yielding the structure *[will [meet Mary]]*, which through a further application of merge will yield the complete sentence *[John [will [meet Mary]]]*. Merge is recursive, in the sense that it can systematically apply to its own output, a structure already created by Merge. So one can extend a sentence indefinitely, step after step: for instance, the previous sentence can be merged with the complementizer *that* and become an embedded sentence, to be merged with a verb taking a sentential complement like *say,* which could ultimately yield a complex sentence like *[Peter [could [say [that [John [will [meet Mary]]]]]]].* So, this simple formal property appears to be responsible for one of the most striking properties of human language, its unbounded scope.

As far as we know, no other communication system used by other species has similar properties. Merge thus appears to be a good candidate to capture an ultimate root of what is special and unique in human language (Hauser, Chomsky, & Fitch, 2002). Let me go back to this point in the final section, after introducing a few other technical elements of linguistic analysis.

4. Merge and cross-linguistic variation

All human languages are merge-based, in the sense that they involve hierarchical structures built by progressively merging selecting words ("heads") and selected words or phrases. This hierarchical structure may be superficially blurred in part by the fact that languages vary in the rigidity or freedom of the word order, but even the freest languages are sensitive to certain hierarchical properties of prominence such as c-command (Reinhart, 1976), if tested with sufficient care. The degree of "free word order" seems in fact to be a function of the availability of certain movement operations (on which see below) on structures uniformly created by Merge. If the "vertical" hierarchical structure created by Merge is by and large constant, what clearly varies is the "horizontal" arrangement of elements, the linear order. For instance, a verb phrase has a constant hierarchical structure, with a selecting verb merged with a nominal object, but the order may be VO, as in English, or in the African language Chicewa (Baker, 1988), or OV, as in Latin or Japanese:

(3) Chicewa: Njuchi [zi-na-wa-lum-a alenje]
'bees bit hunters'

Japanese: John-ga [Bill-o butta]
'John Bill hit'

About half of human languages are VO, and half OV (Baker, 2001). This is a prominent case of another major feature of human language: its variability. Language differs from other human systems, such as the visual system, in this respect. The language faculty, the biological basis for language, is consistent with many possible realisations, the different human languages, mutually incomprehensible systems diverging along various structural dimensions.

If variability is an obvious property of language, there is another equally important but less obvious property to take into account. Linguistic research has shown that there are severe limits to language variation: the rules of human languages never exploit all the logical possibilities: they vary within a tiny fraction of the class of conceivable formal rules (Baker, 2001, but see Evans & Levinson, 2009 for a dissenting view). For instance, many languages have rules exploiting the "second position", i.e. there are verb second languages, clitic second languages, etc., but no language seems to have rules for third, fourth, fifth position in the sentence: i.e., a rule can require an element to be adjacent to the initial constituent, hence in second position, but languages do not have "counters" of positions. So, we have many "verb second languages" with the inflected verb in second position (as, in slightly different forms, all modern Germanic languages in main clauses, except English), but no "verb fifth" language.

We have no special trouble in learning an artificial language exploiting "fifth position" (say, a language in which the verbs always is the fifth word), but natural languages simply don't work like that. As Musso et al. (2003) have shown, the acquisition and use of an artificial rule like the one exploiting "fifth position" involves the activation of neural structures distinct from those involved in the acquisition and use of a "possible linguistic rule", like verb second; (see Moro, 2008 for discussion of these issues).

Linguists are therefore confronted with the problem of expressing invariance and variation in natural language: describing the observed variety of linguistic structures while at the same time capturing linguistic universal and limits on variability. A very successful model to achieve these goals was introduced about a quarter of century ago. The central idea is that the language faculty can be modelled as a system of principles and parameters. The principles express the invariants, the linguistic universals; and a system of binary parameters expresses the limited ranges of permissible variation (Chomsky, 1981).

Let us go back to the VO/OV alternation. One can generalize this observation by stating a binary ordering parameter:

(4) The head precedes/follows the complement

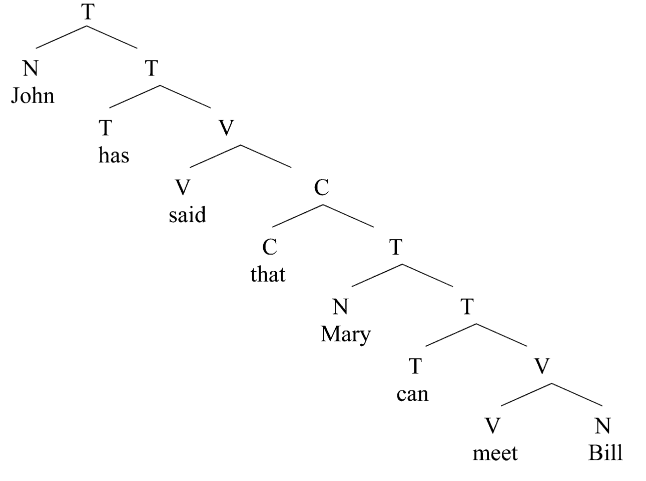
(see also Kayne, 1994, 2000 for an alternative approach involving a parameter on movement). The majority of languages coherently fixes (4) in the same manner for all heads, as was observed by Joseph Greenberg in his pioneering work (Greenberg, 1963); there can also be "incoherent" languages adopting different values for different heads, but there are important limits to the permissible incoherence (Biberauer, Holmberg, & Roberts, 2009). English and Japanese are languages coherently fixing the parameter on the initial or final value, respectively. In such cases, this elementary property of variation gives rise to major and pervasive word order differences, as illustrated by complex sentences in the two languages:

(5) a John has said [that Mary can meet Bill]

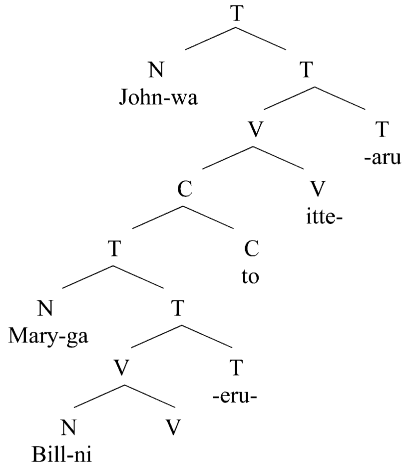
b John-wa [Mary-ga Bill-ni a - eru- to] itte-aru
'John-Top [Mary-Nom Bill-Dat meet-can- that] said-has

The difference is even more apparent if we express the sentences with tree structures like the following, in which each application of Merge is expressed as an elementary subtree. The English tree is systematically right branching, while the Japanese tree is almost systematically left branching (not completely though, because some properties, such as the subject – predicate articulation, remain constant):

(6) English:



(7) Japanese



The fundamental word order is just one property which varies across languages. The challenge that parametric theory accepted was to express all syntactic variation in terms of binary choice points like (4). Ever since the early eighties, proposals of parametrisation have proliferated, but they are by and large reducible to a very restrictive format. A parameter is an instruction to perform a certain syntactic action: so, we have Merge parameters, having to do with basic word order, as in (4); Move parameters, having to do with the triggering of movement operations (on which see below), Spell-out parameters, having to do with the licensing of unpronounced position (e.g., the Null Subject Parameter, differentiation languages which permit zero pronominal subject like Italian, Spanish or Swahili from languages which do not have this option, like English: ___ *partirà domani*, *___ *will leave tomorrow*, see Rizzi, 1982).

Going back to the main point of this section, one of the fundamental tasks of linguistics is to capture invariance and variation in human languages. Parametric models have been particularly successful in highlighting the fundamental uniformity and the limited but non-trivial dimensions of variability. The language of principles and parameters has turned out to be very well suited for expressing invariance and variation; so it is not surprising that the study of comparative syntax flourished from the early eighties on in an unprecedented way.

5. Acquisition as parameter setting

How are cross-linguistically variable properties acquired by the language learner? Let us focus again on a major property like word order. When the child starts producing two-word utterances with some systematicity, around the end of the second year of life, his/her productions already conform to the basic word order of the language: the child acquiring English typically produces VO utterances, the child acquiring Japanese typically produces OV utterances, which suggests a very early fixation of parameter (4) (Wexler, 1998). But the point is controversial: Tomasello (2000) has argued for an acquisition of ordering properties case by case, for individual lexical items, and then a much later generalization to all members of a given grammatical category. Nevertheless, other recent experimental data seem to strongly support the hypothesis of a very early fixation. For instance, Gervain, Nespor, Mazuka, Horie, and Mehler (2008) have exploited the remarkable statistical capacities of babies to show their early sensitivity to abstract word order properties. These authors presented utterances from an artificial language to 8 months old children, with very frequent "words" sometimes preceded, and sometimes followed by less frequent "words"

(8)	a	W1 +freq	W2 -freq
	b	W1 -freq	W2 +freq

They showed that 8 months old babies raised in an Italian speaking environment prefer pattern (8)a, while 8 months old babies raised in a Japanese speaking environment prefer (8)b. Their conclusion is that the child at this age has already categorized function words and contentive words on the basis of frequency (function words being much more frequent than contentive words) and possibly other cues; moreover, they have observed that in the language they are exposed to a function word typically precedes (if head initial) or follows (if head final) a contentive word (e.g., the auxiliary precedes the contentive verb in English (6), and follows the verb in Japanese (7)); then at 8 months the language learners are able to immediately generalize this abstract knowledge to the artificial language.

Earlier work by Christophe, Guasti, Nespor, and Van Ooyen, (2003) had shown that 3 months infants are already sensitive to certain prosodic cues typically differentiating head initial and head-final languages, suggesting the possibility of a "phonological bootstrapping" of the headedness parameter. In fact, the idea that the headedness parameter may be bootstrapped very early on, via prosodic or statistical cues, makes a lot of sense: headedness has such pervasive effects that even the parsing of the most elementary sentences must refer to it; so it is extremely useful for the child acquiring a language, even at a pre-lexical stage in which s/he is trying to extract the first lexical items from the linguistic "noise" which surrounds him/her, to have a very early indication of whether his/her language is head initial or head final.

If we phrase the acquisition of syntax in terms of a process of parameter setting, a central descriptive goal for acquisition and development studies is to identify the temporal map of parameter fixation. It appears that certain kinds of parameters, like most word order parameters, are fixed from very early on, before syntactically relevant production starts (i.e., before the two-word stage: Wexler, 1998), while other parameters, e.g. those concerning the licensing of certain null elements, are fixed later on (Hyams, 1986); the latter cases are also of great interest, but for a different reason: the child appears to go through developmental phases in which his/her production is not adult like, and nevertheless expresses options that are attested in some other adult languages. This suggests that in some cases the child explores certain corners of the grammatical space open by the human language faculty without immediately converging to the target adult system. The theory-guided study of language acquisition and development is now focused on these issues: it is critical, in the first place, to arrive at a detailed descriptive map of how parameter setting takes place in time; and then to arrive at a better understanding of the internal causes which lead the child to quickly converge to the target system in the case of some basic parameters, and to systematically explore non target-consistent options in other cases (see Rizzi, 2006 and, more generally on selective acquisition procedures, Changeux, 2002; Mehler & Dupoux, 1992; Piattelli-Palmarini, 1989).

6. Move and search

If Merge deals with structure building, another operation profoundly affects syntactic structures and determines the surface pronounced forms of sentences: movement. We can characterize the movement, or "displacement", property in a vary general fashion as follows:

(9) Some elements are pronounced in positions different from the positions in which they are assigned certain interpretive properties.

For instance, in interrogative constructions like the following,

(10) a Which book should I read ___ ?
b Which book do you think I should read ___ ?
c Which book do you think the professor said … that I should read ___ ?

the phrase *which book* occurs in clause initial position, but must be understood as the object (patient) of the verb *read*, which can be indefinitely far away from it. The classical way to express such dependencies in generative grammar is to postulate an abstract representation in which the element is in its interpretive position (in this case, the position adjacent to the verb, in which it receives the thematic role of patient, as in (11)a) and then have it move (possibly in successive steps) to clause initial position, as in (11)b:

(11) a I should read which book

b Which book I should read ___

Certain syntactic frameworks claim that they can do away with movement. But if movement is construed in the abstract and general manner indicated in (9), the postulation of such long-distance dependencies between positions ("concrete" positions in which an element is pronounced, and "abstract" unpronounced positions, in which the element receives certain interpretive properties like thematic roles) is inevitable, it's just an inherence feature of natural language syntax. So, no formal framework which aims at describing natural language syntax can do away with a formal mechanism expressing such long-distance dependencies.

While traditional models of generative grammar expressed the dependency in a way close to the movement metaphor (the element is physically displaced from one position to another, as in (11)), Minimalism views movement as a complex operation consisting in the combinations of two simpler operations: Search and the by now familiar Merge. The process is triggered by a functional head, in this case a special complementizer designating a question, null in English (except in certain environments such as *if* in embedded yes-no questions), but expressed by an overt question particle in other languages. This element acts as a "probe", triggering a search of an appropriate candidate, a wh phrase, in the case of a question:

(12) Q [I should read [which book]]

Once the search successfully terminates with the identification of an appropriate "goal", in languages like English the goal is (re)merged with the whole structure, yielding

(13) [Which book] Q [I should read <[which book]>]

The phrase *which book* now occurs twice, in the two positions corresponding to the two kinds of interpretive properties that it bears: it is an interrogative operator, with scope over the whole clause (a main question), and part of the argument structure of the verb *read*, its thematic object (patient). Typically, only the higher occurrence of a phrase is pronounced. The lower copy (expressed within angled brackets in (13)), remains silent: the "trace" of movement. "Movement", in fact decomposed into the two more elementary operations of Search and Merge, can be interpreted functionally as a device to associate two kinds of interpretive properties to a syntactic phrase: properties of **argument structure**, thematic roles such as the agent, patient, or experiencer; and **scope-discourse** properties such as the scope of a question operator, or topicality, focus, etc.

Here too we observe various forms of parametrisation. While all languages presumably involve search from a head in the complementizer system to some kind of question operator, some languages like English involve subsequent (re) merge of the element thus identified, while other languages leave the wh phrase *in situ*, in its canonical clause internal position. Chinese and Japanese are classical *in situ* languages, but also colloquial French in main clauses has the option of leaving the wh phrase *in situ*:

(14) Q Tu as lu quoi ?
'You have read what ?'

Thus, principles and parameters are operative in the movement system as well.

The idea that movement is a complex operation is supported by the fact that the two components Merge and Search can be dissociated and exist independently. Pure Merge obviously exists independently as the fundamental structure-building operation. Search may be dissociated from Merge in cases like (14), and many other cases in which a dependency is created between two positions without involving movement, as in the assignment of an antecedent to an anaphoric expression like a reflexive:

(15) *John* will speak about *himself*

That the same general kind of Search operation may be involved in anaphoric dependencies, *in situ* constructions, and the identification of the candidate for movement (and in many other cases, such as the licensing of polarity items) is suggested by the fact that analogous conditions of configurational prominence (c-command) and locality (intervention effects of the kind referred to as Relativized Minimality: Rizzi, 1990) appear to hold in all these cases.

7. Conclusions: some questions for the study of language and the brain

Jumping now from more technical points of linguistic analysis to the broader issues of language and the brain, let us venture on some more general questions raised by the approach to syntactic structures I have just presented. One class of questions concerns the inventories:

(16) What neural structures support the inventories? Do categorial distinctions matter? Are there critical differences between the contentive and the functional lexicon in the brain?

Recent work on the N vs V distinctions in the brain (e.g., Shapiro, Moo, & Caramazza, 2006) is promising in supporting the view that categorial distinctions may involve distinct neural networks. The attempt of identifying neural structures supporting different kinds of syntactic categories should be systematically extended to the functional- contentive distinction: given the very different properties of contentive and functional elements and the clearly distinct role they play in syntax we would expect this distinction to be systematically honored by the brain.

Various important questions concern parameters, parameter setting, and computations:

(17) How is the headedness parameter expressed in the brain? And other major parameters? How are they fixed? Does parameter setting involve brain structures distinct from other forms of learning?

(18) What brain structures subserve the fundamental syntactic operations of Merge and Search? Is there evidence for or against the hypothesis that movement is a composite operation combining Search and Merge? Are these computational ingredients domain-specific? Or domain-general? And at what levels?

We could expect the setting of fundamental parameters (particularly those for which a pre-lexical bootstrapping is plausible) to involve specialized neural structures with respect to other forms of learning, say, the acquisition of a new lexical item; but the question is open, and no evidence is available so far.

The question of the specificity also arises for the fundamental computational ingredients. Are Merge, Search and Move domain-specific, or domain-general? Are certain structural constraints operative on linguistic computations, such as locality and prominence (c-command), specific to language? Or are they domain-specific embodiments of domain-general computational constraints? And at what level of aggregation does the specificity emerge?

Let me conclude with some remarks and questions on recursion. The recursive property is critical in characterizing the two systems of discrete infinities which humans are good at: language and the number system. No other animal species seems to possess a communication system which permits the mastery of a discrete infinity of messages (Hauser, 1997), and no other animal species can count (many species are good at roughly estimating quantities, but that's a very different kind of cognitive ability from precise counting: Dehaene, 1997).

So we would want to know:

(19) a. Is there an identifiable neural substrate which implements the recursive property for language in the brain? Is there anything like a "signature" of linguistic recursion? If so, at what granularity of analysis does it emerge? How does it relate to classical areas dedicated to linguistic (Grodzinsky, 2000) and numerical (Dehaene, 1997) capacities, or to language-related cultural skills, such as reading (Dehaene & Cohen 2007)?

b. Do these mechanisms relate in a non-trivial way to the mechanisms responsible for other kinds of hierarchical structures in other cognitive domains, vision, navigation, motor control, the theory of mind and the other cognitive capacities ruling social interactions?

c. How did the mastery of recursion for communication and other human cognitive systems evolve in the natural history of the species (Hauser et al., 2002)?

We do not know what the answer may be to these questions, but it is not too far-fetched to imagine that partial answers are within reach, through the conjoined efforts of formal modelling of cognitive capacities, the study of pathology, and the brain imaging techniques; these questions will probably keep the scientific community of cognitive neuroscientists busy in the years to come.

Immediately connected to the question of the neural basis of the linguistic computations is the phylogenetic question. In a recent article, Hauser et al. (2002) have put forth the speculation that the availability of recursion for the communication system (and perhaps derivatively for the number system) may have been a sudden and recent event in evolutionary history, perhaps the major consequence of a minor reorganization of the brain which had been growing steadily for millions of years, and that this single evolutionary event may be at the root of the acquisition of what paleoanthropologist Ian Tattersal calls "the human capacity", the collection of cognitive capacities which makes our species so different from the others. These speculations currently are at the extreme periphery of scientific understanding; nevertheless, here too it is imaginable that a joint interdisciplinary effort of formal modelling, the brain sciences, and comparative ethology may permit serious advances on evolutionary aspects of language and other human cognitive capacities, which have so far resisted serious scientific inquiry.

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