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5. What do you think is the proper place of recursion? Conceptual and empirical issues

Arie Verhagen

1. Introduction[1]

The "recursion-only-hypothesis" tentatively put forward by Hauser, Chomsky, and Fitch (2002) – henceforth: HCF – holds that "recursion" might be the only component of the Faculty of Language in the Narrow sense ("FLN"), with "narrow" being defined as: Neither shared by other organisms, nor shared by other cognitive capacities than the faculty of language, so being both unique to humans and unique to language at the same time[2]. This suggestion has generated many responses, from students both of human cognition and of animal behavior. Especially the latter responded not only to HCF, but also to Fitch and Hauser (2004); although published two years after HCF itself, this article had already been invoked by HCF (1578, col.1) as a study suggesting some empirical support for the hypothesis, so it is understandable that the scientific community took the two as directly linked. Fitch and Hauser showed that cotton-top tamarins could easily master regularities in certain strings of sounds that were

1. I would like to thank Dan Everett for organizing a stimulating conference, and him as well as Peter Harder, Jan Koster, Bob Ladd, and Marianne Mithun for stimulating discussions at the conference. Thanks are also due to Carel ten Cate and Jelle Zuidema for discussions on some evolutionary and formal issues, that allowed me to – hopefully – find suitable formulations for what I wanted to say in these areas. Three anonymous reviewers provided useful feedback on the first draft, which led to a number of changes and additions. But as usual, I am solely responsible for any remaining errors.
2. In HCF, "FLB" – "B" standing for "Broad sense" – comprises all capacities an organism must possess in order to be said to have language. So FLB includes FLN by definition, and also much more that is, in one form or another, also used in at least one other cognitive domain, present in at least one non-human animal, or both. Notice that FLN may be empty, under this definition (cf. Fitch, in press, who also provides some other clarifications).

defined by a finite state grammar (FSG); these strings were of the type $(AB)^n$ (A and B representing two classes of sounds differing in some salient respect), and the animals could learn to distinguish legitimate from illegitimate strings, as defined by this grammar. But what they could not learn, apparently, was to distinguish legitimate from illegitimate strings as defined by a phrase structure grammar (PSG); in this case, legitimate strings were of the type A^nB^n, thus involving center-embedding introducing long-distance dependencies (Fitch and Hauser 2004: 378). Although they do not use the term "recursive" itself, it is clear that Fitch and Hauser (2004) are in fact referring to this property, since the term *is* used for exactly the same phenomenon in HCF (1577, col. 3), and since it is graphically illustrated by means of figure 1, showing nested embedding of pairs of AB in each other in the second case, as opposed to the non-embedding structure for strings of the type $(AB)^n$.

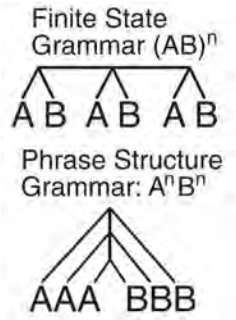

Figure 1

It was the idea that animals are intrinsically incapable of processing "recursive" structures conceived in this way that was addressed by Gentner et al. (2006). Using exactly the same types of grammars to construct their own stimulus materials, they showed that European starlings *were* capable of learning the regularity in A^nB^n patterns, i.e., to distinguish legitimate from illegitimate strings as defined by this grammar, and they thus concluded that at least this non-human species has the capacity to acquire a recursive grammar. Given the character of HCF's "recursion-only-hypothesis", this conclusion naturally generated a considerable amount of interest and discussion as well.[3] The reason is that this line of research promises to provide

3. Something that did not receive much attention, even though Gentner et al. are quite explicit about it, is the fact that there was much individual variation in the performance of the birds: Only 4 out of 11 individuals learned to do the task well, and 2 never showed any progress. Moreover, an extremely high number of trials was needed, though the birds depended on their performance for their food. Thus, the task was apparently very difficult, and the results suggest that the capacity for recursive processing had to be *learned* and was not biologically given a priori, such that it only had to be "triggered" by exposure to stimuli; in that case, one would not expect so much variation despite a large amount of training.

part of the answer to the question what makes human language so special and powerful as compared to animals' communicative abilities.

However, there is an issue that we should take into account before any such comparison can be made at all, viz. the question whether "recursion" is sensibly *identified* with long-distance dependencies, for the purpose of testing a hypothesis about a biologically and cognitively unique characteristic of language. Fitch and Hauser (2004: 378, col. 3), in line with HCF, assume so, despite the fact that they acknowledge that center-embedded structures are "less common in human language than other (e.g., right-branching) structures"; they write: "This PSG thus provides the ideal grammar for the empirical issue addressed by this study". The argument is essentially that there is "a broad consensus in linguistics and machine learning that PSGs are more powerful than FSGs and that grammars above the FSG level are, minimally, a crucial component of all human languages" (col.1), and that the A^nB^n grammar is a minimal PSG. However, as argued by Zuidema (2005), the observation that all FSGs (to which animal communication systems are generally assumed to belong) are included in the set of PSGs and that human languages are beyond the power of FSGs only *suggests* that precisely this boundary corresponds to an evolutionarily relevant step, but it is not at all clear that this is actually the case. First, there are many PSGs that bear little or no resemblance to human linguistic systems; "[n]atural languages are [...] constrained in many ways (e.g., semantics, learnability) that have nothing to do with the Chomsky Hierarchy". Second, the idea of evolution "climbing the Chomsky Hierarchy" suggests that more formal power than FSG is hard to get, but it is actually extremely easy (Zuidema 2005: 50). So it is still necessary to raise the question formulated above: How much sense does it make to identify "recursion" with long-distance dependency, or more to the point: What sense of "recursion" is useful in the light of empirically sound generalizations concerning the structure of human linguistic utterances? Most of the remainder of this article is concerned with this question; the discussion will involve both conceptual and empirical considerations. What we will

see is that it makes little sense to view recursion as a property at the global level of a language's grammar as a whole; it is much better viewed as a "local" property of certain subparts of a grammar.

2. Different formulations in 20th century linguistics

The role of recursion to account for long-distance dependencies goes back to Chomsky's initial work on formal models for the description of grammar. To make the point that a natural language cannot be described by means of a Finite State ("Markov") model, Chomsky (1957) drew attention to English sentences of the following form:

(1) (i) If S_1, then S_2.
(ii) Either S_3, or S_4.
(iii) The man who said that S_5, is arriving today.

In such sentences, a dependency between two elements exists, though they can be indefinitely far apart: "between the interdependent words, in each case, we can insert a declarative sentence S_1, S_3, S_5, and this declarative sentence may in fact be one of ([1]i–iii)" (22), i.e., the kind of process HCF allude to when they write (1577): "Natural languages go beyond purely local structure by including a capacity for recursive embedding of phrases within phrases, which can lead to statistical regularities that are separated by an arbitrary number of words or phrases." But in Chomsky (1965), the primary role of recursion is to account for the property of productivity: "The infinite generative capacity of the grammar arises from a particular formal property of these categorial rules, namely that they may introduce the initial symbol S in a line of a derivation. In this way, the rewriting rules can, in effect, insert base Phrase-markers into other base Phrase-markers, this process being iterable without limit." (142). This role for recursion is *also* present in HCF, but then at the beginning of the article (1571):

> All approaches agree that a core property of FLN is recursion, attributed to narrow syntax in the sense just outlined. FLN takes a finite set of elements and yields a potentially infinite array of discrete expressions. [...].
>
> The core property of discrete infinity is intuitively familiar to every language user. Sentences are built out of discrete units [...]. There is no longest sentence (any candidate sentence can be trumped by, for example, embedding it in "Mary thinks that..."), and there is no non-arbitrary upper bound to sentence length. [...]
>
> At a minimum, then, FLN includes the capacity of recursion.

There is indeed a connection between these two roles of recursion: Arbitrary long-distance dependency (recursion role 1) implies that the length of a sentence is unbounded (thus there is no longest sentence) and this in turn implies an infinite number of sentences; and similarly, a mechanism for embedding phrases/sentences in other phrases/sentences also implies that there is no longest sentence, and thus an infinite number of sentences (recursion role 2). But does the fact that these two mechanisms produce the same result of unboundedness mean that they are identical, as the use of the term "recursion" for both cases suggests? Obviously, unbounded long distance dependency implies the existence of embedding (phrases within other phrases of the same type). But is this a relation of equivalence? Is this implication bi-directional? In other words: Does embedding of sentences imply the existence of long-distance dependencies?

Another question relates to a presupposition in both of Chomsky's formulations: Is it truly the case that all instances of the category S (i.e., any phrases categorized as "sentences") can be embedded in each other? This question concerns the proper level of abstraction of a recursive analysis of some linguistic construct. I will begin by addressing this latter issue, as it is also relevant for a discussion of the first one.

3. Roles and types of recursion, and their empirical counterparts

3.1. Adverbial subordinate clauses

The first construction invoked by Chomsky (1957) to illustrate long-distance dependency in English concerns an adverbial clause type (*if... then*). But contrary to Chomsky's suggestion, it is practically impossible to embed an *if... then* construction in itself, or, for that matter, in *either... or*, in ordinary English (while such constructs are run-of-the-mill in computer programming):

(2) ??*If if it rains, then they will cancel the match, then I will not buy a ticket.*

(3) ??*Either if Federer won, then Nadal lost, or the Wimbledon finals have not taken place yet.*

There seems to be a quite general restriction: Center-embedded clauses cannot be headed by the same conjunction as the embedding clause. For example, 109 (=about 1%) of the over 10,500 subordinate clauses in the Dutch Eindhoven corpus contain another, center-embedded clause, and of these, only 1 has the same conjunction as the embedding clause:

(4) [*Als jij haar* [*als je thuis kwam*] *waarschijnlijk vriendelijk en blij tegemoet kwam,*] *waren haar goede voornemens weer op de loop.*
'[When/While you, [when you came home,] were probably nice and friendly,] her good intentions were gone again'

Notice that the *content* of the relation marked by the two instances of *als* is not entirely the same; the first is more or less concessive, the second purely temporal. These observations have a natural interpretation in terms of the assumption that human memory, unlike a computer, does not work with basically arbitrary addresses, but is rather content-driven. Interrupting the processing of some construct requires that the intermediate result be correctly retained in memory for processing to be resumed later, and this is much more problematic when the interrupting sequence has the same kind of content. Example (5), the English equivalent of one of the Dutch corpus sentences, also illustrates this:

(5) *Because our flight turned out to be cancelled when we arrived in Madrid, we missed our connecting flight in New York.*

(6) ?? *Because our flight was cancelled because the Spaniards were on strike, we missed our connecting flight in New York.*

Embedding a temporal relation in the middle of a causal one leads to a much better sentence (5) than embedding a causal relation in another causal one (6). A more radical, but arguably simpler and better way of putting it, is to say that, for the cognitive system, cases like (5) do not involve recursion at all, because the embedding and the embedded sequences are actually not of the same category, and hence the whole sentence does not satisfy the elementary definition of recursion: That a constituent is embedded in another one *of the same type*. If it is the embedding of a temporal relation into a causal one that a cognitive system has to process in (5), then this does not involve two constituents of the same type. This is in fact a much more general issue, as we will see.

Let me explain here why usage data like the ones just considered are particularly relevant in the present context, which involves a discussion of evolutionary issues. In this context, it is important to keep in mind that it is only through behavior that a cognitive trait can interact with the environment, so it is only through behavior that such a trait can be selected for (give an organism an advantage). So if an organism with an alleged language-related cognitive trait T is indistinguishable *in linguistic usage* from one without T, then there is no evidence that T has been selected for (it does not have to be selected against, either, of course), and thus there is no explanation why it should have become dominant in the population. In other words: Then there is no reason to assume that the emergence of T is part of the explanation of the evolution of language as we encounter it today. For the adverbial clauses under consideration, this seems to make sense: Since strictly recursive adverbial clauses (involving embedding of the same type of clause in itself) do not have to be produced or processed, a verbally communicating organism without the capacity to embed adverbial clauses of type X into themselves will be indistinguishable from one with that capacity in actual linguistic usage; in a sense, there will not really be opportunities to use the capacity to some advantage in the linguistic environment, and thus it will not increase in frequency in the population.[4] Of course, this does not mean that the same

4. In principle, if the same behavior could be produced using less resources (energy, time), due to the presence of recursion, than without recursion, then it may also be a target of selection. For instance, a grammar with recursion may be smaller in size, requiring less memory space, while still describing the same language; or it may be learnable in a smaller amount of time. This cost-advantage is certainly operative in evolutionary processes, a prime example being conspicuous signals that are indicative of the health or fitness of an individual (in competition or sexual attraction), where individuals that are able to produce them at lower costs have an advantage (albeit with subsequent loss of value of the signal as a consequence). While such a mechanism cannot be excluded a priori, the fact that it is possible in principle does not undo the relevance of the point about observable behavior. For one thing, it should be demonstrated separately that, for instance, reduced grammar size provides an advantage in terms of memory load, as this depends on the way memory works and the availability of memory capacity (which is quite impressive in humans, to say the least), and on potential additional disadvantages elsewhere. In the case of "true recursion", in particular, a well known problem is that although the statement of a rule may itself be very simple, processing requires a "push down stack" to store intermediate results of computations for a potentially indefinite amount of time and an indefinite number of times, which produces costs for working memory that may not outweigh the benefits for long term memory; the fact that such structures are actually very difficult to process for humans, suggests that at least this kind of recursion is not hard-wired into us (I will return to this in the conclusions). Secondly, and most importantly in the present context, effects of traits in terms of behavior interact more directly with the relevant environment and have a more directly observable effect than cost effects, so the former should always be considered as prime candidates when considering the question whether the trait in question can have been the target of selection.

conclusion also holds for other alleged areas of grammar where recursion has been claimed to be operative; each should be investigated in its own right.

3.2. Recursive non-finite clauses?

One such area is that of causative constructions, since these are mostly analyzed as involving an embedded S, albeit an infinitival one. Consider the English and Dutch examples (7) and (8).

(7) *He made me understand the situation.*

(8) *De sergeant liet de rekruten door de modder kruipen.*
The sergeant let the recruits through the mud crawl
'The sergeant had/made the recruits crawl through the mud.'

These are usually analyzed as in (9), expressing the linguistic generalization that *the recruits* has the same role with respect to *crawl* as a full-blown subject has in a finite clause with *crawl* as its main verb:

(9) [$_S$ *The sergeant made* [$_S$ *the recruits crawl through the mud*]]

Considering usage again, this analysis predicts that in a particular corpus, the ratio of transitive and intransitive embedded non-finite Ss is the same as for embedded finite clauses. After all, analyzing the embedded phrase in (9) as an S amounts to assigning it the same grammatical status as a tensed sentence, essentially claiming that the value of the feature finiteness is irrelevant to its syntactic category. If finite and non-finite phrases are indeed of the same syntactic category, then one should expect that the overall distibution of subtypes of the category (such as transitive vs. intransitive) is the same within a particular corpus, since the subtypes should also be indifferent to the feature of finiteness. So, given that a causative clause has one additional argument (the subject of the matrix verb), the ratio of three- to two-participant causative clauses should be the same as that of transitive to intransitive finite clauses. However, in the Dutch Eindhoven corpus, the *actual* ratios are 10% three-participant causatives to 90% two-participant ones, while the transitive-intransitive ratio is 40%–60%. This is not only a very big difference, the 10% three-participant clauses is also about the same as the portion of *di*transitive clauses (mainly events of transfer) within the set of *monoclausal* transitives.

Not only does this suggest that the representation in (9) might be ascribing an overdose of structural complexity to causatives. So far I have not found actual cases of causatives *embedded in* causatives, i.e., sentences like the constructed examples in (10) and (11); and as a matter of fact, these are at least strange, too:

(10) ??*John let me make his son understand the situation.*

(11) ??*Deze opmerking deed de sergeant de rekruten door de modder laten kruipen.*
'This remark made the sergeant have the recruits crawl through the mud'[5]

Another piece of linguistic evidence that causatives share more properties with monoclausal structures than with biclausal ones (cf. Kemmer and Verhagen 1994, Verhagen and Kemmer 1997), is the fact that the selection of expressions marking the role of the causee (the alleged subject of the alleged embedded clause) operates at the level of the combined predicates, not at the level of either one of the two hypothetical clauses. Consider the Dutch example (12).

(12) *Je mag die brief aan niemand laten lezen.*
You may that letter to nobody let read
'You must not let anybody read that letter.'

The preposition *aan* is used in simplex sentences to mark indirect objects as recipients (typically with *give*). Here it marks *nobody* in precisely that way. But neither *laten* ('let') nor *lezen* ('read') selects a recipient role; it is the combination *let read* that does.

Again, all this indicates that the actual categories used by the cognitive system to process causative structures are of different types (presumably, a very limited set of grammaticalized, auxiliary-like causal predicates on the one hand, and a more open class of result predicates on the other). So they are not of the same type, and embedding one in the other therefore does not actually constitute recursion. And in any case, an individual lacking the capacity to embed causatives recursively would be indistinguishable, in practice, from one having it, so the fact that it is *possible* to analyze

5. Notice that these constructed cases have different causal verbs, in order to avoid the "content-restriction" alluded to in the previous section.

these structures as biclausal does not provide evidence for the presence of recursion in the biologically given, universal faculty of language.

3.3. Finite complements and tail-recursion

The prototype of syntactic recursion, also invoked by HCF, is complementation: Embedding of an arbitrary tensed sentence in a matrix of the type "Mary thinks/says/knows that…". Unlike the non-finite complements of causatives, these actually *can* be embedded in each other; it is not hard to find instances like (13) in actual texts.

(13) *This gentleman thinks that I do not know it is a doll.*

Arguably, this is directly related to the fact that complementation expresses a kind of content that is itself recursive, viz. perspective-taking, a cognitive capacity – putting oneself in someone else's shoes, thus ascribing to them one's own cognitive capacities, including perspective taking – that implies recursivity (cf. Verhagen 2005: 98–99).

At the same time, it is important to notice that the general capacity to embed complement clauses in other complement clauses develops gradually during language acquisition. Children start out with using highly fixed phrases like *I think…*, *I guess…*, *you know…*, *Look…*, each with its own specific function in managing the triadic relationship between themselves, their interlocutors and some object of shared attention (Diessel and Tomasello 2001; Tomasello 2003). It is only later, with increasing linguistic experience, that they generalize it to a pattern, or rule, for embedding clauses into clauses. Children do not start making complex sentences by combining the simplex clause types they have acquired at a certain point, rather they start adding certain initially different fixed elements to their utterances, out of which a pattern for complex sentences ultimately emerges as a generalization. In fact, the fixed expressions and their specific interactional functions remain available, and continue to play a prominent role into adulthood especially in spontaneous conversation, where they account for the vast majority of "complementation sentences" (Thompson 2002).

It is especially in writing (printed public texts) that the operation of a generalized pattern for complementation can be observed. In Verhagen (2005: 102–104), it is shown that the four most frequent complement taking predicates account for only about 25% of complement constructs in newspaper texts, while predicates with a token frequency of 1 or 2 account for as much as 50%. In contrast, in Thompson's (2002) conversational

data, the four most frequent predicates account for over 80% of the data, with a single verb, *think*, accounting for over 50%. While the type-token ratio in the conversational data is .26, it is .59 in the newspaper texts.

It seems reasonable to assume that it is to a large extent the process of learning to read and write that is responsible for the increase in people's linguistic experience that allows generalized embedding of complements (beyond just tagging relatively fixed expressions onto other clauses) to become a productive process, especially by causing the *type*-frequency (the number of *different* lexical items occupying the same slot in a pattern) of complement taking predicates to increase in people's linguistic experience (cf. Bybee 1995 for the relation between type-frequency and productivity). Thus, it is proposed in Verhagen (2005: 111) that the knowledge of complementation constructions of an adult speaker of Dutch can be (partially) represented as the construction network in figure 2:

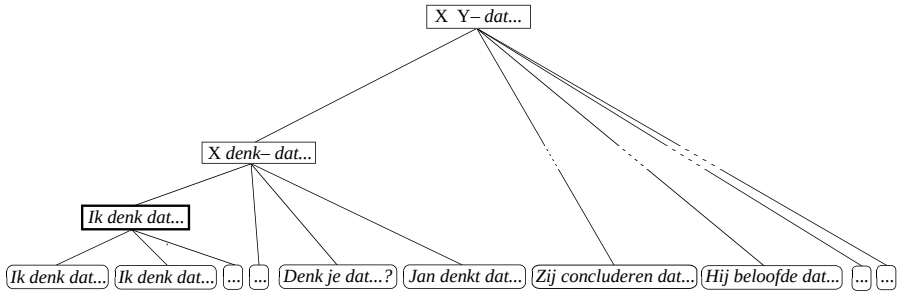

Figure 2

Initial fixed expressions ("I think", etc.) are still available for processing, and in fact well entrenched (indicated by the bold lines). But generalized versions (e.g., the verb *think*) are also available on the basis of experience with similar but somewhat different instances, and ultimately also an abstract pattern (at the top of figure 2), on the basis of experience with different forms occurring in formally and functionally similar environments.

But while actually instantiated, the type of recursion allowed in complementation clearly does not produce center-embedding. Rather it involves what is known as tail-recursion, which does not require the special memory requirements (a "stack", to maintain intermediary results when processing must be interrupted) that is needed for processing center-embedding (the latter is also known as "true recursion"). So here we have an empirical answer to the first question raised in Section 2: Embedding of

one S in another certainly does not necessarily produce center-embedded structures, so the two roles for which recursion has been invoked in Chomsky (1957) and (1965) respectively, and in HCF at the same time, certainly do not entail one another.

However, complementation is assumed to be the domain of a particular phenomenon that has received much attention in theoretical linguistics and that does seem to produce long-distance dependencies, viz. *Wh*-movement. This is what I will turn to as a final case (cf. Section 3.3.5 of Verhagen 2005 for a more detailed account).

3.4. Long-distance Wh-*movement*

Consider examples (7) and (8) (Chomsky's (1977) examples (32) and (10)).

(14) *Who did Mary say that John kissed* t.

(15) *Who did Mary hope* [$_{\overline{S}}$ *that Tom would tell Bill* [$_{\overline{S}}$ *that he should visit* t]]

We seem to have very clear cases here of displacement. The element *Who* in (14) is the object of *kissed*, but it is not included in the clause of which *kissed* is the main verb, so it seems to pose a computational challenge: How do language users manage to interpret the role of the *Wh*-element when it is not included in the same unit that determines this role? The challenge is even larger, it seems, when one realizes, in view of (15), that the number of clauses between the elements to be connected may be indefinitely large (so the phenomenon indeed appears to instantiate true recursion).

However, when looking at actual linguistic usage again, it soon becomes clear that utterances containing apparently displaced *Wh*-elements share quite a few *other* specific properties as well. For example, 10 out of the 11 instances in the Brown Corpus have *think* as complement taking verb (the other one is *say*), and 9 have a second person pronoun as its subject, i.e., a reference to the addressee of the question; cf. (16).

(16) *What do you think I did with them?*

That there is indeed a high degree of lexical and grammatical specificity of long-distance *Wh*- sentences is strongly confirmed when we look at a larger corpus, in this case a whole year (1995) of the Dutch newspaper *de Volkskrant*. In this corpus, we do find some more examples with other verbs than *denken*, e.g., *willen* ('want to') in (17), and other subjects than second persons, such as *Mayor and Aldermen* in (18).

(17) *Waar wil je dan dat ik het over heb?*
Where want you then that I it about have
'What do you want me to talk about then?'

(18) *Wat denken B en W dat onze burgers*
What think Mayor and Aldermen that our citizens
zullen denken van zo'n dure buitenlandse reis?
will think of such-a expensive foreign trip
'What do Mayor and Aldermen think that our citizens will feel about such an expensive trip abroad?'

Still, the verb *denken* ('think') and second person subjects are strongly favored. *Denken* accounts for 34 of the 43 instances; the other verbs are *willen* ('want to'), *zeggen* ('say'), and *vinden* ('find, believe'). Second person accounts for 36 of the 43 cases; the other subjects are third person pronouns, definite noun phrases, and a first person pronoun. Thus, there is clear evidence for the entrenchment of a specific template for prototypical "*Wh*-extraction" in Dutch that has the form given in (19).[6]

(19) [*Wh* . . . – *denk-* pron$_{2nd}$ *dat* . . .]

In fact, the entrenchment of this template seems to be stronger than that of many idiomatic expressions. The frequencies of the verbs and the subject types differ dramatically from their overall frequency in the corpus, and the corpus does not contain "*Wh*-extraction" cases that differ from (19) in more than one respect. Also, a few of the 7 subjects that are not grammatical second persons, are demonstrably referring to the *addressee* of the question, so conceptually still second persons (including the case of a first person matrix subject; cf. Verhagen 2005: 129–131); for example, (18) was uttered by a city council member while addressing Mayor and Aldermen. It is also clear that the other verbs occurring in this pattern are the most basic verbs of communication, volition, and "opinion" (*vinden*). Thus, the patterns licensing all cases are minimal, less well entrenched, extensions from the prototype template in (19).[7] And so far, I have not been able to find examples like (15) in actual usage.

6. Its English counterpart could be [*Wh* . . . do pron$_{2nd}$ *think* . . .] (cf. Dąbrowska 2004, chapter 9).
7. Indeed, it is conceivable that some instances of use, at least for some speakers, are direct extensions from the prototype, constructed ad hoc, rather than licensed by independent templates.

Consequently, actual instances of patterns that are usually analyzed as combinations of abstract pieces of structure (i.e., clauses) and involving apparent violations of the boundaries between these abstract structural units, turn out to be produced and understood on the basis of a much more specific template. The lexically specific part *denk je* ('do you think') exactly parallels the part *I think* in the "complement taking" formulaic templates underlying children's early complementation-like utterances, and those found in spontaneous conversation (cf. Section 3.4). It marks the subjectivity of the person whose mind is being "put on stage": The speaker's (*I think*) in the case of assertions, the addressee's (*you think*) in the case of questions (Verhagen 2006). The template thus occupies a similar "low-level", well-entrenched position in the network of complementation constructions (cf. figure 3).

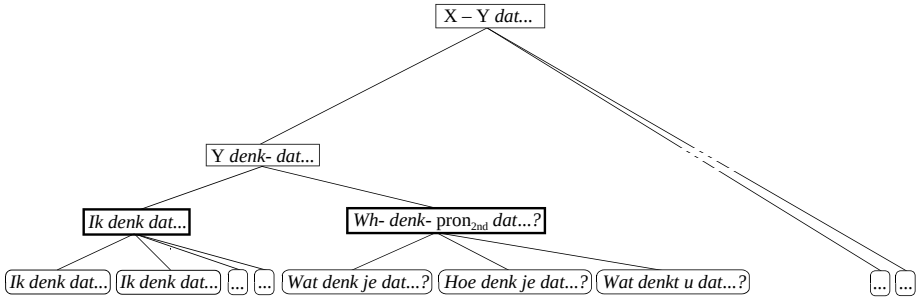

Figure 3

Actual constructs such as (16)–(18) are not the result of combining abstract clausal structures (from the top of this network), embedded in each other. Low-level templates inherit properties of higher nodes in the network, but can have additional properties as well; thus, specific properties of lower-level templates do not as such license inferences about properties of the more abstract nodes in the network. Again, it appears that for the cognitive system, the embedding of a clause in this template involves different categories, not categories of the same type, hence it does not amount to recursion. Again, an individual lacking the capacity for clausal recursion but equipped with this memorized specific question-forming template would be indistinguishable in actual linguistic usage from an individual with the recursive capacity.

4. Conclusions

Summarizing, we have first of all found that it is necessary to keep different aspects and different types of recursion well distinct, and investigate each of them separately. The general point is that the behavior of one kind of phenomenon that can be put in the very general rubric of "recursion" does not predict the behavior of other phenomena that have been put into the same rubric. The identity-requirement for recursion is not easily met in actual linguistic phenomena, indicating that this rubric may simply be too general for many descriptive and explanatory purposes. Hence the necessity for keeping different types and aspects apart, both conceptually (e.g. true and tail recursion) and analytically: Differences between linguistic phenomena that may be claimed to exhibit recursivity (e.g. adverbial clauses, complementation, *Wh*-movement) are as important for explaining their actual properties as this point of similarity, if not more so.

By the same token, a general conclusion of the type "Recursion is irrelevant in natural language" is not licensed by the present considerations either. Recursive phenomena exist, and can be an important feature of specific *parts* of the grammar of a language. Complementation, as expressing perspective-taking, is such a part. Other areas that come to mind are those of referential specification (e.g., by means of relative clauses), or of locating something in space ("zooming in" by means of prepositional phrases of the same type embedded in each other).

Second, there are some important consequences for views of the evolution of language, grammar in particular. It is clear that *built-in* general recursion cannot have given verbally communicating organisms an advantage. Present day language use does not provide evidence that there has been a selective pressure in our evolutionary past favoring a variant with a general recursive syntactic capacity such that it became more and more frequent in the population over subsequent generations.

There is no reason to assume that the capacity for recognizing center-embedding patterns (true recursion) is built into humans, just us there is no reason to do so for starlings (cf. footnote 3). In fact, it is well known that processing center-embedded structures is generally hard for humans. In view of the content-restriction on center-embedding, it is perhaps not even clear a priori that all humans would be equally able to recognize the purely formal regularity that at least some of Gentner et al.'s starlings were capable of picking up.

It is also quite telling that one of the clearest types of actual, general

syntactic linguistic recursion – complementation – is not immediately available to children, but needs time and experience to develop. I have suggested that the development of literacy in an individual's life may play an important role in the *general* complementation pattern becoming a productive rule, since it is especially through the interaction with texts that the type frequency of this pattern increases dramatically in a person's linguistic experience. Following this line of thought, the hypothesis suggests itself that it may very well also have been the development of writing systems, and their spreading through human populations, that created the basis for the evolution, i.e., the *cultural* evolution, of general recursion in this area of the grammars of the languages involved. Literacy, especially reading, leads to communication between larger numbers of individuals and thus contributes to an increase in variation in linguistic experience, especially if it is wide-spread in a population. Moreover, writing, as an external representation of linguistic utterances, provides individuals with an extension of their memory, and thus also facilitates the recursive use of grammatical patterns (not only "true" recursion).[8]

A parallel with the number system is useful here. As is well known, recursion in our number system is a product of cultural evolution. The development of the place-value system, including the invention of zero which made it possible to distinguish between 11, 101, and 110, was a gradual process. Each step simplified the task of performing calculations on paper (rather than with an abacus). Ultimately, once the recursive number system was in place, it expanded the cognitive abilities of its users, partly by providing the basis for the invention of more dimensions of numbers (negative numbers, infinity, rational numbers, etc.), partly by allowing routinization and internalization. Surely, we do not want to say that the recursive number system (and its ramifications) has been part of all humans' cognitive make-up for millennia before it was "discovered" a few centuries ago, when it became possible to start *using* it (in those parts of the world that had access to the discovery . . .). The only view that makes sense is that recursivity is a *truly* new property, having emerged on the basis of still the same basic cognitive capacities; these happen to apply to new circumstances also emerging from cultural evolution and therefore give rise to truly novel results, not present in the original state of the organism.

8. A specification of some mechanism that actually produces recursive use from a non-recursive initial state of grammars is still required, of course. This issue is taken up in Verhagen and Zuidema (in prep.).

Finally, as to the proper place of recursion, I have argued that this should not be thought of as a single spot in the grammar of a language, let alone in language. Rather, as far as grammar is concerned, it is to be found in different forms and with different constraints, in different "niches", associated with a particular kind of content. As far as domains of evolution are concerned, the proper place of recursion is definitely not only to be sought in genetic evolution, but (at least) also in cultural evolution. Both points, especially taken together, imply that we should actually expect a considerable amount of variation to occur, in individuals, in populations, and through historical time, since the conditions leading to recursivity of certain patterns – linguistic experience for generalization, functional content favoring recursive expression, memory capacity, cultural-environmental conditions providing means of external representation – are not equally available everywhere all the time. It seems to me that the reality of linguistic usage actually fits this picture rather well.

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