Recursion and Human Language

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Preliminaries

Re Recursion[1]

Harry van der Hulst

> "We hypothesize that FLN only includes recursion and is the only uniquely human component of the faculty of language." (Hauser et al. 2002: 1569)
>
> "If you already know what recursion is, just remember the answer. Otherwise, find someone who is standing closer to Douglas Hofstadter than you are; then ask him or her what recursion is."[2]
>
> "An apparently new speech disorder a linguistics department our correspondent visited was affected by has appeared. Those affected our correspondent a local grad student called could hardly understand apparently still speak fluently. The cause experts the LSA sent investigate remains elusive. Frighteningly, linguists linguists linguists sent examined are highly contagious. Physicians neurologists psychologists other linguists called for help called for help called for help didn't help either. The disorder experts reporters SpecGram sent consulted investigated apparently is a case of pathological center embedding."[3]

1. Introduction

The present volume is an edited collection of original contributions which all deal with the issue of recursion in human language(s). All contributions (but one[4]) originated as papers that were prepared for presentation at a conference organized by Dan Everett on the topic of recursion in human

1. I wish to thank the following people for comments on an earlier draft of or ideas contained in this chapter: Jonathan Bobaljik, Marcel den Dikken, Laszlo Hunyadi, Fred Karlsson, Simon Levy, Marianne Mithun, Geoffrey Pullum, Barbara Scholz and Arie Verhagen. Needless to say that some points that I did not remove from this final version met with strong disagreement.
2. Attributed to Andrew Plotkin (http://en.wikipedia.org/wiki/Recursion).
3. http://specgram.com/CLI.2/03.bakery.disorder.html
4. The exception is chapter 17. In an earlier draft of this introductory chapter I included a section on phonology that I had to remove because it was too long. The reviewers suggested that I turn this section into a separate contribution to this volume, which I did.

language (Illinois State University, April, 27–29 2007).[5] For the purpose of this collection all articles underwent a double-blind peer-review process. The present chapters were written in the course of 2008.

The characterization of language as a potentially infinite number of expressions that can be produced with finite means has been noted for a long time, among others by the linguists Panini and Wilhelm von Humboldt. Chomsky's early work (e.g. Chomsky 1955 [1975]) proposes various ways to build recursive mechanisms into the grammar (cf. below) and since then many linguists have adopted one of these mechanisms, namely a rewrite or phrase structure component which contains recursive rewrite rules or recursive rule sets (cf. below). However, no general agreement seems to exist concerning the empirical status as well as the formal status of this 'characteristic' of human languages or the grammars that underlie them.

Renewed interest in this subject was sparked by claims made by or attributed to, Hauser, Chomsky and Fitch (2002) which I paraphrase as follows:[6]

(1) a. Recursion essentially constitutes the innate human language faculty[7]
    b. Recursion is the sole uniquely human trait of human language
    c. Recursion is unique to the language faculty
    d. Recursion is universal (i.e. present in all human languages)
    e. Recursion is unique to the human mind

As one might expect, all these bold claims are controversial. According to the first claim, language results from several mental faculties whose intersection leads to language, as well as from necessary 'natural laws' of some kind that take scope over language (and, presumably many other phenomena). However the *recursion faculty* (also called the *narrow language*

5. Dan Everett wishes to thank Bernard Comrie and the Max Planck Institute for Evolutionary Anthropology and the College of Arts and Sciences and the Provost of Illinois State University for financing this conference.
6. There is some uncertainty on what the authors of this article say precisely and different interpretations can be found in reactions to it. My focus here is on the kinds of claims that linguists have attributed to the article.
7. Together with the so-called interfaces to the sensory-motor system and the conceptual system, it forms the 'narrow language faculty'. This claim constitutes an interesting and indeed minimalist interpretation of Chomsky's Innateness Hypothesis which, originally, had it that human are born with a richly articulated universal grammar.

faculty) is properly contained in this intersection. The second claim adds that all other language-relevant faculties than recursion (which together with recursion make up the *broad language faculty*) can also be attested in non-human animals, while recursion cannot. Pinker and Jackendoff (2005) contest the first claim by pointing to other aspects of language that specifically serve language (being confined to the intersection, which goes against claim a). Thus, for them, the innate language faculty contains more than recursion. They also imply that at least some of these other aspects may also be unique to human minds (which goes against claim b). They also note that recursion seems to play a role in other human cognitive systems such as the 'mathematical module', or 'social intelligence' which runs against claim c. Hauser, Chomsky and Fitch have responded to their article (Fitch, Hauser and Chomsky 2005) which has sparked a further rebuttal by Jackendoff and Pinker (2005). With respect to claim (d), Everett (2005) finds that Pirahã, a Muran language from the Brazilian Amazon, does not exhibit any recursive structures at the syntactic level. His claim has been called into question in Nevins, Pesetsky and Rodriguez (to appear) to which Everett (2007, to appear) is a response. This claim, which has attracted a lot of attention in the professional literature and in the popular press, has contributed to further interest into the matter of recursion.[8] Finally, claim (e) has been called into question by Genther at al. (2006) who report on experiments which show that European starlings can be trained to make a distinction between strings that result from recursive or from non-recursive grammars. These findings, which also gained media attention, have received alternative interpretations (cf. Language Log[9]; Marcus 2006), notably the idea that making a distinction between $a^n b^n$ and random combination of a's and b's may point to an ability to 'count' (in itself still a remarkable capacity). In fact, Hauser, Chomsky and Fitch (2002) themselves note that animal navigation capacities can be analyzed as containing recursion, which implies that recursion may not be entirely limited to the human mind.

In this volume, the question of recursion is tackled from a variety of angles. It is perhaps fair to say that the conference call invited participants to take a critical stance regarding the claims in, or attributed to Hauser, Chomsky and Fitch (2002) and this is certainly reflected in the present

8. See the discussion on the Edge website (http://www.edge.org/3rd_culture/everett07/everett07_index.html)
9. http://158.130.17.5/~myl/languagelog/archives/003076.html.

very interesting collection.[10] Some articles cover empirical issues by examining the kinds of structures in languages that suggest recursive mechanisms, focusing on the question to what extent recursive constructions can actually be attested in natural language use. Others focus on formal issues, notably what kind of devices can be used to describe the apparent recursive expressions, and whether the relevant devices have the specific function of making recursion possible or, perhaps lead to recursion as an epiphenomenon. Most articles discuss syntactic phenomena, but a few involve morphology, the lexicon and phonology. In addition, we find discussions that involve evolutionary notions and language disorders, and the broader cognitive context of recursion.

In this introductory chapter, section 2 offers a brief discussion of the use of the notion recursion in linguistics and, for the sake of discussion, some further remarks about the role and source of recursion as a morpho-syntactic device. Then, in section 3–9 I will review the content of the chapters in the order in which they appear in this volume.[11] In some sections I include some additional discussion, particularly in areas which are less well represented in this collection, such as derivational morphology and phonology. Section 10 summarizes what I believe to be the major claims or considerations that are contained in this volume.

2. 'Recursion as hierarchical grouping' allows 'specific recursion' as a possibility

A general problem with the HCF article is that it does not define precisely enough what it means by recursion (cf. Tomalin 2007: 1796). Tomalin (2007) and Parker (2006) clearly show that the concept of recursion and of recursive functions (in linguistics, mathematics and computer science) can be defined in several different ways. When one gets down to specifics, mathematical formalizations are intricate and inaccessible to most people, including most linguists. In addition, there are different notions of recursion around and to disentangle their formal differences is, again, largely a

10. Another conference on recursion was held May 26–28, 2009 at the University of Amherst. This conference reflected as less critical view of the centrality of recursion. The centrality of the recursion topic, or the related topic of complexity is further evident from two other conferences that focus on this issue, June 19–20, 2009 and February 24–26, 2010, both in Berlin.
11. The description of the articles' content is based on abstracts that were provided to me by the authors.

topic for advanced mathematical minds. Tomalin (2007) presents an overview of the historical background of this notion in generative grammar, pointing to connections to work outside linguistics as well as different ways in which the notion appears within generative grammar, and, more specifically, within the Minimalist Program.[12] He shows how Chomsky, faced with the problem of designing a grammar that could generate an infinite number of expressions with finite means, introduces different 'recursive devices' in different parts of LSLT (Chomsky 1975 [1955]). In LSLT, chapter 7, it is suggested that a finite set of rewrite rules can be applied more than once. Then in chapter 8 rewrite rules are considered that have the symbol on the left of the arrow also appearing on the right side of the arrow. It is this notion of recursion that became more widely adopted in generative grammar, by Chomsky and others. Thirdly, in chapter 10, the recursive part of the grammar is located in the transformational component where "the product of a T-marker can itself appear inside the P-base of a T-marker." (LSLT, 516–518; Tomalin 2007: 1793).

Tomalin also distinguishes at least five different notions of recursion and concludes that the type of recursion that HCF refer to (that conforms to the Minimalist Program) is perhaps best characterized as the idea of providing an *inductive definition* (indeed also called *recursive definition*) for linguistic expressions. In the MP "the operations of C_{HL} recursively construct syntactic objects" (Chomsky 1995: 226) which means that every syntactic object (i.e. linguistic expression) can be defined in terms of a combination of smaller syntactic objects, with lexical items being the 'base case' syntactic objects (that thus terminate a derivation). This characterization of recursion is more general than what most linguists usually have in mind when they define recursion as 'embedding a constituent in a constituent of the same type'. However, it could perhaps be argued that this latter notion of recursion (which I here will call 'specific recursion') is entailed by the more general notion.

Let us agree that linguistic expressions (words, sentences) can be analyzed as hierarchically structured object ('trees') for which, following LSLT, we can formulate rewrite rules that capture parts of these structures, such as:

(2) $A \Rightarrow B + C$
(often paraphrased as "An A can consist of a B plus a C")

12. Parker (2006) also provides a detailed overview of the way linguists, mathematicians and computer scientists use or define this notion.

B and C can be atomic units (morphemes in morphology, words in syntax), or they can be combinations themselves (called *complex words* or *phrases*). If that latter option is allowed (as it seems to be in linguistic expressions which do have complex words inside (necessarily) complex words and phrases inside phrases) this means that we have rewrite rules of the following sort:

(3) a. Phrase ⇒ Phrase + X
    b. Word ⇒ Word + X

'X' in (3a) can be another phrase or a word, while in (3b) it can be a word or an affix. I assume here the idea that X is the *head* of the phrase to the left of the arrow and will return to the notion of headedness below.

The recursive step of an inductive definition, when formalized as a rewrite rule, can be 'recognized' by the fact that the symbol on the left of the arrow also occurs on the right. In (3a) and (3b) the identical symbol is 'word' or 'phrase', respectively. In fact, if the difference between complex words (morphology) and phrases (syntax) is ignored or even denied, there is only one rewrite rule, effectively 'concatenate' or, more fashionable: 'merge':

(4) Linguistic expression ⇒ Linguistic expression + X

If we agree that the designation 'linguistic expression' literally implies units *of the same type* (namely the type 'linguistic expression') rule (4) meets the classical characterization for recursion: it has the same symbol on both sides of the arrow.

When Chomsky says that C_{HL} recursively constructs "syntactic objects" he characterizes such objects as follows (Chomsky 1995: 243):

(5) a. lexical items
    b. $K = \{\gamma\{\alpha\beta\}\}$, where α, β are objects and γ is the label of K

Starting out with a set of lexical items, the rule in (5b) recursively constructs (binary) units until all members in the 'numeration' are dominated by some K_{γ}.

With (5a) being the base case that allows the construction to terminate, (5b) is the recursive step (corresponding to 4). Given the 'definition' in (5), a complex syntactic object K, if well-formed, can be recursively defined into combinations of (smaller) syntactic objects (which may be complex of simplex). Let us call this notion of recursion here 'general recursion'. Again, mostly, linguist identify recursion as cases in which a *specific* rule

(from a set of rules) is applied (directly, or indirectly) to its own output, but if there is only one rule (i.e., rule 4), *every* expression that contains another non-basic expression involves recursive application of that rule. However, the more specific understanding of recursion presupposes the idea of linguistic expressions being of a variety of different *categories*. Words are nouns, verbs, prepositions etc., while phrases are noun phrases, verb phrases, prepositional phrases, etc. Thus, instead of the rule in (4) we have rules as in (6). (Having linguistic expressions of different categories allows us to formalize the idea that linguistic expressions have heads that determine the category):

(6) a. XPhrase ⇒ YPhrase + X
    b. XWord ⇒ YWord + X

This allows cases in which X and Y are identical, which then presents the 'Russian Doll' effect: a phrase of type X within a phrase of type X, or a word of type X within a word of type X. The difference between general recursion and specific recursion is exemplified in the following quote from Pinker and Jackendoff (2005: 10):

> "...(As mentioned, HCF use "recursion" in the loose sense of concatenation within hierarchically embedded structures). Recursion consists of embedding a constituent in a constituent of the same type, for example a relative clause inside a relative clause (....). This does not exist in phonological structure: a syllable, for instance, cannot be embedded in another syllable."

There is, however, no contradiction between these two characterizations of recursion: the 'specific recursive case' is an automatic result of having general recursion, which means there is no need to regard *specific recursion* as a basic property. What *is* basic is the possibility of containing non-atomic objects within larger non-atomic objects *of the same complexity* and thus the idea of unbounded hierarchical structure. In a system of this sort specific recursion occurs unless it would be explicitly blocked. In other words, if phrases are allowed to occur inside larger phrases then finding a noun phrase inside a noun phrase is an expected consequence:

(7) NP ⇒ NP + X (where X = N, the head)

Rule (7) is a *specific* case of rule (6a). All things being equal, there is no reason to complicate a grammar by blocking rules like (7), especially if expressions occur which seems to be the result of rules like (7).

Rule (7) produces *direct* specific recursion, i.e. a NP which contains a

NP as one of its daughters. We also expect *indirect* specific recursion:

(8) a. $S \Rightarrow NP + VP$
b. $VP \Rightarrow V + S$

In this case S contains another S as a granddaughter. The nodes linked in terms of indirect recursion can be separated by an indefinite number of intermediate nodes.

Both general and specific recursion are possible because the complex expressions that can be contained in (necessarily) complex expressions are of the same complexity type (although possibly belonging to different categories). A different kind of system would result if the general schema for rewrite rules would be as in (9):

(9) $\text{Phrase}^{n+1} \Rightarrow \text{Phrase}^{n} + X$

In this case, self-feeding is excluded because each application introduces a new type of expression. Rewrite rules of this kind, in the more specific form of (10), have been suggested to underlie the so-called prosodic hierarchy (see van der Hulst, this volume):

(10) $\text{Phrase}^{n+1} \Rightarrow \text{Phrase}^{n} + \text{Phrase}^{n}$

An indeed, given this rule format, prosodic structure would not be recursive. This also drives home the point that hierarchical structure as such does not entail recursion.

In conclusion, general recursion ('merge') makes specific recursion a possibility which in turn makes it possible that grammars, being themselves finite, can generate an **infinite** number of linguistic expressions. In other words, recursive mechanisms are held responsible for the apparent discrete infinity of natural languages in the sense that when languages are thought of as sets of expressions, these sets are infinite. This is what Pullum and Scholz (this volume) call the *infinitude* claim. The infinitude claim also involves the idea that there is no limit on the potential length of linguistic expressions ('there is no longest sentence'). However, whether it is 'true' that languages cannot be said to have a finite number of expressions is an empirical question, although, as Pullum and Scholz show, linguists generally assume that the infinitude claim is true. And therefore, these linguists design grammars that have recursive mechanisms.

Tomalin (2007: 1797–1798) notes that "if the sole requirement is to generate an infinite number of structures using finite means, then an itera-

tive, rather than a 'recursive', process could accomplish this, and while such a procedure may be less efficient than a 'recursive' procedure, the basic point is that a requirement for infinite structures using finite means is not itself sufficient to motivate the use of specifically recursive procedures." In defense of recursion it could be said that iteration does not adequately capture the recursive nature of the semantic structure that syntactic objects are supposed to encode. In other words, one could claim that syntax uses recursion because recursive syntactic structures express complex thoughts which themselves display this kind of combinatorial capacity. Note that, if this is so, then this specific recursive capacity is not unique to (morpho)syntax because it also characterizes our 'conceptual constellations' (using this as another term for our 'thoughts'). The conceptual structure of 'a bird in a tree on the hill', which itself displays recursion (indeed specific recursion), if needed to be expressed, 'inspires' or 'drives' a syntactic system that iconically builds similar structures, i.e. structures that allow complex entities to be part of even larger complex entities.

The claim that morphotactics uses recursion to directly express the recursive nature of conceptual structures is controversial for those, like Chomsky, who regard syntax as an autonomous system and as such, the core of human language.[13] But autonomous does not have to mean unmotivated (or ungrounded).[14] Seeing syntactic recursion in this light allows the possibility that iteration (or indeed other mechanisms such as intonation; cf. below) *could* be used as conventional ways of expressing recursive conceptual structures. Syntactic recursion (if interpreted realistically, i.e. as forming part of the grammars that people have in their heads) may be the best solution because of the achieved iconic *isomorphy* between syntactic and conceptual structure, but it need not be the only one. This, indeed, is the essence of Everett's claim about Pirahã (Everett 2005, 2007a,b, 2008).

The above reasoning (controversial as it may be) locates the source of recursion in the general recursive structure of the conceptual system. It is sometimes suggested that there is a particular conceptual basis for this kind of conceptual recursion, namely the human *theory of mind* which suggests a kind of embedding:

(11) {I think {that she thinks {that he thinks...}}}

13. See Uriagereka (2009) for a defense of the idea that the relationship between syntax and semantics works in the other direction: syntax constructs semantics.
14. The claim that syntactic structure is semantically grounded is central to Anderson's notional grammar (e.g., Anderson 1997).

However, it could be said that the conceptual structure 'a bird in a tree on the hill' which does not presuppose a theory of mind has the same kind of embedding:

(12) {a bird {in a tree {on the hill}}}

In this case, however, conceptually, the tree is not contained in the bird, nor is the hill contained in the tree. If anything, the containment runs in the other direction: the hill, as the larger structure, contains the tree and that tree contain the bird.

In any event, whether or not the (emergence of a) theory of mind, underlies conceptual recursion, we do not have to make a fuss about conceptual recursion either; it simply results if the conceptual grammar allows hierarchical grouping. If recursion is a side effect of allowing hierarchical grouping that allows units of the same complexity type to occur inside each other, this applies as much to the conceptual grammar as it does to the syntactic grammar.[15]

3. Types of specific recursion

In addition to the distinctions made in the previous section, various types of *specific* recursion are usually distinguished; cf. Parker 2005 and Kinsella [Parker], this volume, Karlsson, this volume and Verhagen, this volume. An important distinction is that between *nested recursion* (*center-embedding, central embedding, self-embedding*) and *tail-recursion* (the latter covering *left-recursion* and *right-recursion*). It is also important to contrast recursion with *iteration*. Karlsson (this volume) distinguishing six types of iteration (structural iteration, apposition, reduplication, repetition, listing and succession).

Let us first illustrate and discuss nested recursion.

(13) Nested recursion
[The man [the boy [the girl kissed] hit] filed a complaint]

This 'classical type of example' is, however, quite atypical of recursion in language because not a single genuine one has ever been attested (Karlsson, this volume). But other cases of nested recursion do occur; cf. below. In

15. Note that if the grammar of 'conceptual objects' is recursive and if this 'conceptual system' is not seen as part of 'universal grammar', recursion cannot be unique to C_{HL} if this system only comprises recursive syntax.

nested recursion, a constituent occurs 'in the middle' of another constituent such that the latter constituent has material on either side of the former constituent, which makes the latter a *discontinuous constituent*. Center-embedding can be further differentiated in several subtypes (cf. De Roeck at al. 1982; Sampson 2001: 13–14), depending on the degree of identity of the embedded units and the unit that contains it. One degree of center-embedding passes by unnoticed, but two degrees or more are often considered 'difficult' and Reich (1969), in fact, argued that sentences with center-embedding are 'ungrammatical'; see also Christiansen (1992). Whether or not this is so, it is true that nested recursion is notoriously difficult to process if it exceeds one instance of embedding, although some aren't all that difficult (cf. De Roeck et, al. 1982; Thomas 1995), e.g.:

(14) [The fact [that the teenager [who John dates] was pretty] annoyed Suzie]

In De Roeck et al. (1982), entitled 'A myth about center-embedding', it is reported that spontaneous, and apparently perfectly acceptable cases of multiple center-embedding do exist. Sampson (2001) reports various additional real-life cases such as:[16]

(15) a. [but don't you find [that sentences [that people [you know] produce] are easier to understand]?

b. [the only thing [that the words [that can lose –d] have in common] is, apparently, that they are all quite common]

c. [The odds [that your theory will be in fact right, and that the general thing [that everybody's working on] will be wrong,] is low]

The first sentence was constructed by Anne de Roeck and then posed to Sampson as a question after he had just claimed, following the dogma at the time, that multiple center-embedding is rare and difficult to process. After having collected several examples in the de Roeck study and in his own later study, Sampson concludes that, although his data are not based on language corpora, multiple central embedding is certainly not ungrammatical and in many cases not that difficult to find and understand after

16. Marcel den Dikken (p.c.) notes that all three examples have a copular verb in the root sentences which, perhaps makes them easier than examples with non-copular verbs. He also notes that in (15c) the copular does not agree with its subject, a possible indication that the speaker of this sentence lost track of its structure.

all. This leaves open the question what the differences are between cases that are not that difficult, even having three degrees of embedding, and cases that apparently are, such as the apparently short and simple artificial examples in (16):

(16) a. [The man [the boy [the girl kissed] insulted] left]

b. [I met the man [who saw the girl [who left this morning] this afternoon] two minutes ago]

I refer to Thomas (1995) for a review of attempts to narrow down the properties of constructions that pose clear problems and to Karlsson, this volume. Below I return to nested embedding.

But first, we turn to tail recursion.

(17) Tail recursion

a. Left edge (creating a left-branching structure)
[[[John's] sister's] dog's] bone was found in the yard

b. Right edge (creating a right-branching structure)
[This is the car [that hit the boy [who crossed the street]]]

We can clearly see that a critical difference between nested and tail-recursion is that the former involves long distance relationships (i.e. relations between two units that are separated by other units), while the latter does not. This difference, according to many, explains why nested recursion is much more difficult to process. It is usually said that tail recursion does not pose problems, although it seems to me that (17a) is certainly harder than (17b); cf. Karlsson, this volume. Informally, the difference is that while we can interpret each new relative clause locally as applying to the adjacent noun, (17a) requires us to accumulate the result of each combination so that the genitive '*s* can be interpreted as a property of the steadily growing combination.

Returning to nested recursion, as displayed in the sentences in (16), it is often said that such cases involve a string of the form a^nb^n, which can be generated by the context-free grammar in (18):

(18) a. $S \Rightarrow aSb$

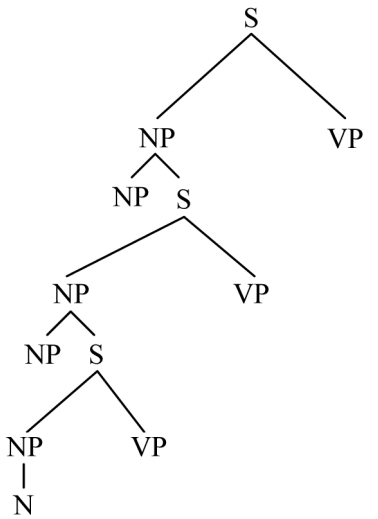
b. $S \Rightarrow ab$

(18) generates a string in which 'S' occurs in the middle of a constituent S. However, it is not clear at all that grammars of real languages have rules like (18a). The rule that is responsible for the center-embedding in (16) is the same rule that causes tail-recursion in (17b):

(19) $NP \Rightarrow NP + S$

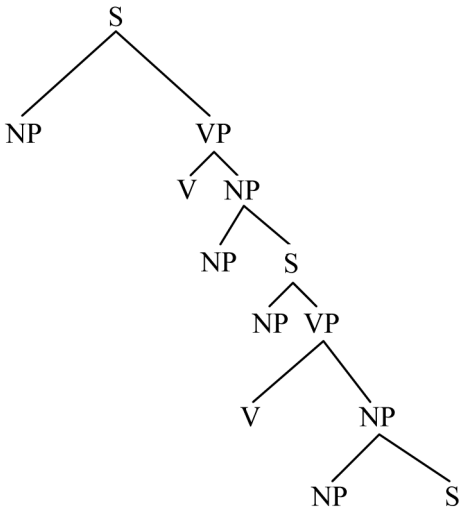
However, the effect of (19) is different depending on whether it expands an NP that is in subject position or a NP that is in object position. At least in most current syntactic frameworks, there is no mechanism to generate a constituent that is literally in the middle of the constituent that immediately contains it if constituents are always binary (which would disallow rules like 18a). Thus (16a) has something like the following structure:

(20)



(15b) on the other hand has the following structure:

(21)

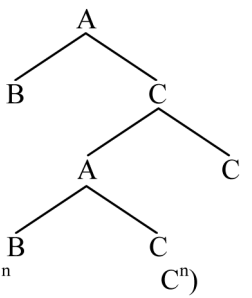


In other words, the bracketing in (16) is incorrect. As shown in (20) the recursive node S does not occur *inside* any constituent, but rather at the right edge of Noun Phrases. What this means is that there is no special mechanism for center-embedding (such as the rule in 18a). Rather center-embedding results in the following situation:

(22) a. $A \Rightarrow B + C$

b. $C \Rightarrow A + C$

c.



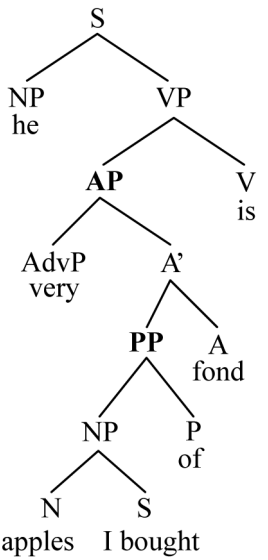
d. C is a right hand expansion of A while A is a left hand expansion of C (or vice versa)

Whenever we have two rules that meet the criterion in (22d) we have what is called center-embedding. What this means is that once special recursion is available (which it is once groupings can involve groupings), center-embedding is available too, unless rule pairs that meet criterion (20) would be explicitly blocked.

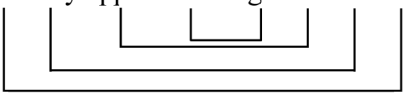
The special feature of center-embedding that makes the relevant constructions hard to process, is that it creates *discontinuous* (long-distance) relationships between B's and C's going from both edges inward. However, it should be noted that this feature is logically independent of center-embedding; see also Verhagen's contribution to this volume. The structure in (23) has no special recursion, thus no center-embedding, yet it creates three discontinuous relationships. Even though this structure is obviously ungrammatical in English it is so because the head complement relations, all being final, are non-English. One would think that in a language with the appropriate head final structure, an example of this sort could be constructed and that it would pose processing difficulties, just like self-embedding structures do.

Focusing on tail-recursion, several scholars have argued that relevant patterns can be analyzed as instances of iteration (Ejerhed 1982, Pulman

(23) a.



b. "he very apples I bought of fond is"



1986, Parker 2005), and Reich (1969) supports this idea with intonational evidence. Christiansen (1992) draws the conclusion that there are no linguistic phenomena that crucially require recursion if center-embedding is ungrammatical and tail-recursion can be handled with an iterative device.[17] However, the claim that center-embedding is ungrammatical as such is wrong since depth 1 certainly is fine as in "The car I bought cost 1000 dollars".

Because it is always said that phonology is not recursive, it is perhaps interesting to apply a similar argument in this domain. Assume for the sake of the argument that a word can consist of any number of feet. If true[18], there would be an infinite number of possible word forms. However, that does not necessarily require a recursive device. The relevant

17. As just shown, the distinction between self-embedding and tail-recursion may be irrelevant. If specific recursion is blocked (and replaced by an iterative procedure) both phenomena are ruled out.
18. See section 9 and chapter 17 on this matter.

property can be characterized by a rule schema that can be collapsed into one rule using an abbreviatory device:

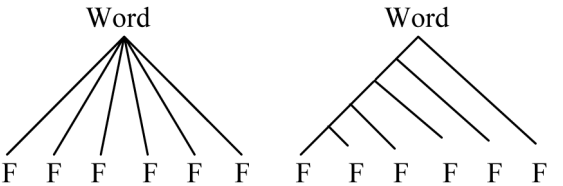
(24) Word ⇒ Foot*

In actual fact, however, a more interesting characterization of the phonological structure of words might appeal to a recursive definition:

(25) Phonological words (recursive definition)
  a. Word ⇒ foot (base case)
  b. Word ⇒ Word + Foot (inductive step)

The two approaches would create different structures:

(26) a. Iterative definition b. recursive definition



Both types of representation have in fact been proposed. (24b) has been proposed in Metrical Theory (Liberman and Prince 1977), whereas the flat representation in (26a) has also been proposed (e.g. Halle and Vergnaud 1987) in the guise of so-called bracketed grids. The question is which representation accounts best for the properties of phonological words. (26b), for example, can be said to express different degree of prominence of feet, about which (26a) has nothing to say. In other words, just like semantic properties may be more adequately expressed in recursive morphotactic structures, phonetic properties may be more adequately expressed in recursive phonotactic structures. These issues are discussed in chapter 17.

Even without considering whether the semantic and phonetic substance that underlies morphotactic and phonotactic structure is recursive, we must ask whether the properties of linguistic expressions which suggest that recursive devices are called for must *necessarily* give rise to these devices. In section 2, I referred to this issue when I said that a recursive structure in morphotactics may be *optimal* as an expression of the presumed recursive nature of conceptual structures, but this does not mean that morphotactics actually achieves the desired isomorphy in all cases, or, in some languages, at all. It may be that the morphotactics is using an iterative device, which puts a bigger burden on semantic interpretation

because the recursive semantics now has to be reconstructed from an iterative morphotactic structure. The same applies to phonotactics. Even if one could argue that the phonetic substance is, in some sense, recursive (in fact, however, I will argue in chapter 17 that it probably isn't), it does not follow that the phonotactics is capable of mimicking this. I briefly return to the question of recursion in phonology in section 9 and more extensively in chapter 17 in this volume.

Several authors in this volume indeed explicitly ask whether the *apparent* recursive morphotactic structures necessarily require a formal recursive characterization. A crucial (although perhaps all too obvious) point that must be born in mind here is that the tactic devices that a linguist proposes (whatever their formal properties) are *hypotheses* or *models* for the system that humans have or use to produce and understand expressions (Itkonen 1976, Tiede and Stout, this volume), i.e., if a *realist* stance is adopted, rather than an *instrumentalist* stance (cf. Carr 1990 for discussion). These hypotheses/models may involve a formal system that uses recursion but this does not entail that the cognitive tactic system used by real people also has recursion, even if we all agree that the conceptual structure that the morphotactic structures encode is recursive. After all, the data that lead the linguist to suspect that the morphotactic system is recursive may also arise from another kind of system such as iteration, supported by intonation devices; cf. Stapert and Sakel, this volume for some explicit ideas.[19]

What the above reasoning misses, though, is the point we discussed in section 2 namely that specific recursion is formally available once we admit that the syntax builds hierarchical structures of a certain kind (cf. 6) which is a claim that perhaps most linguists will agree on. And if recursion is free, then self-embedding is, in principle, available, since it uses the same mechanism as tail-recursion. This means that if one wants to question the modeling choice that entails recursion, one would have to reject the idea that the context-free grammars are required for natural languages (assuming that finite state automata are sufficient).[20] However, this being said, we must also accept that constructions that employ specific recursion, espe-

19. By the same reasoning we can also not take for granted that semantic stuff, or phonetic stuff is or isn't recursive. That too is a modeling choice. See section 3 for some discussion of the question as to whether the conceptual system allows self-embedding.
20. One could also reject constituent-based grammars and turn to pure dependency-based grammars which have no hierarchical constituent structure.

cially when leading to center-embedding effects, are clearly avoided in natural languages, since it creates long-distance relationship which call for special computational machinery involving a stack. Whether the causes of this avoidance are 'dismissed' as performance factors, seriously studied as processing constraints, or even integrated into the (competence) grammar (if a distinction between 'competence' and 'perfomance/processing' is maintained) is another matter. I return to these issues, which are also discussed in various chapters in this volume, in the next sections.

4. Discussing the need for recursion on empirical grounds

Even though all these formal issues are obviously pertinent, we start this collection with a series of chapters that take an empirical perspective. At the empirical level, the question needs to be raised whether (all) languages display recursive structures since it has been claimed that some languages do not have recursive structures at all, or employ (some kinds of) recursion very modestly. Also, we need to know what the precise properties of these recursive structures are. Some of these issues were already raised in the previous section.

In 1995, the linguist Richard Hudson posted the following question on the Linguist List:

> Does anyone know of any *empirical* investigations of center-embedding examples (aka self-embedding) such as the following?
>
> (1) The dog the stick the fire burned beat bit the cat.
>
> I've found lots of discussions (especially in introductory books – the above example is from Pinker's 'The Language Instinct'), but no experimental data (or any other kind of data). There's no shortage of explanations of the 'facts', but there does seem to be a shortage of well-established facts to be explained.
>
> (Richard Hudson on Linguist List (4 December 1995).[21]

Several chapters in this volume provide a different answer to Hudson's question than Sampson's response which I mentioned in the previous section. For languages that have been investigated for the property of recursion *using language corpora*, it has been found that recursion of more than

21. http://www.linguistlist.org/issues/6/6-1705.html

one or two steps is far from common. In spoken language, Karlsson (2007a,b; this volume) finds that self-embedding of degree 2 is virtually non-existent (which apparently contradicts Sampson's admittedly more impressionistic findings). Tail-recursion is not uncommon, especially rightwards, although here actual language data do not show much more than degree 2 recursion. It has of course long been observed that center-embedding of degree 2 and anything higher, even though claimed to be perfectly grammatical (conforming to the design of the linguistic 'competence'; Chomsky and Miller 1963), is rare.[22] This raises the reasonable question how something so marginal can be taken to be so foundational (even definitional as in Hauser, Chomsky and Fitch 2002) for human language. If recursion is a defining feature of human language, as has been claimed, we would expect to find evidence of it in everyday talk, the primary form of language. Chomsky famously asserted that language was not designed to be produced or parsed (understood), meaning that language is not designed to be used as a communication system. Rather it is a system to facilitate thought. Additionally, it is said that language production and parsing belong to 'performance' and it is here, as Chomsky claims, that we find the limitations that limit the use of center-embedding.

A factor that must be recognized in evaluating the 'clash' between the rarity of recursion and its alleged central role in language is that studies of the actual occurrence of recursion focus on *specific* recursion while Chomsky's more recent claims about the centrality of recursion seem to emphasize *general* recursion, i.e. hierarchical grouping.

Bearing this point in mind, let us ask, for the sake of discussion, language why should be recursive in the first place. If syntax emerged and exists, primarily, or perhaps exclusively, to facilitate thought, why was recursion required, if we assume that the conceptual system itself had its own syntax (which, I believe, should be an uncontroversial assumption)? Certainly Chomsky does not equate what he calls 'syntax' with the 'syntax of conceptual structures'.[23] So, if the two are different, why does the mind need 'syntax' only to duplicate conceptual syntax? What is wrong with the syntax of our conceptual system? This is the point where (most) other

22. Rather than evaluating the degree of embedding, Davis (1995), in particular considers different types of center-embedding in terms of whether, for example, a relative clause occurs inside a sentential complement, or the other way around.
23. Some authors such as Burton-Roberts (2000) think that Chomsky should. For Burton-Roberts indeed 'syntax' is the syntax of thought(s).

linguists would say that 'syntax' did not emerge to organize our conceptual system, but to express or *externalize* it (cf. Jackendoff 2002). Together with what we call phonology, syntax is a mechanism to relate conceptual structure to utterances that can be produced and perceived. In other words, in this view, syntax (and phonology) did emerge to make communication (or at least, externalization) possible.

Putting this issue aside as well, and accepting that syntactic objects are distinct from conceptual objects, we must again ask why it is necessarily the case that syntax is formally set up to allow recursion and thus self-embedding? It is said that syntactic objects with self-embedding are difficult to process (in performance), but what warrants their existence in competence (if that distinction is made)? Perhaps, as one might say, the problem is not that humans can't process self-embedding, but rather that our syntactic system does not have this formal trait to begin with. Conceptually, we can understand self-embedding very easily, for example when it is based on visual information. We can see, and understand a circle that contains another circle which contains another circle and so on. Hence our conceptual system permits self-embedding with no apparent limitation, but, playing the devil's advocate, one might say that there is no evidence that the syntax can mimic that, and if that is so, and the distinction between competence and performance is accepted, we cannot process it either. We will not try to produce it because the grammar does not deliver the appropriate input to the processing systems, and we cannot parse artificially produced examples because no parse will lead to a result that is syntactically well-formed. Clearly, we cannot here resolve all these issues, but I remind the reader that this line of reasoning does not take into account that specific recursion and thus self-embedding come for free once one admits that grammars generate hierarchical objects with groupings inside groupings of the same complexity.

Although, as we have just experienced, empirical and formal issues are difficult to separate sometimes (among others because 'data' always imply an analysis of some sort), the following five chapters focus on empirical issues. These chapters show that (a) recursive structures are not very common and (b) where apparently occurring they may result from specific templatic constructions involving specific lexical items (often derived from clearly non-recursive constructions) rather than abstract recursive mechanisms.

Karlsson reports that multiple nested syntactic recursion of degrees greater than 3 does not exist in written language, neither in sentences nor

in noun phrases or prepositional phrases. In practice, even nesting of degree 2 is extremely rare in writing. In speech, nested recursion at depths greater than 1 is practically non-existing. Left-branching tail-recursion of *clauses* is strictly constrained to maximally two recursive cycles. Right-branching clausal tail-recursion rarely transcends three cycles in spoken language and five in written language. On constituent *NP or PP level* both left- and right-branching is less constrained (especially in written language), but e.g. left-branching genitives rarely display more than two recursive cycles ([[[Pam's] mum's] baggage]).

Laury and Ono also supply data on the use of recursion in real speech. However, they first discuss certain methodological problems that arise when one tries to establish the use of recursion in conversation. First, there is the tendency for certain types of main clauses to become grammaticized as discourse particles, in which case it is not clear whether a given item should be counted as a particle or a clause. Secondly, the authors discuss the problematic nature of the category 'sentence'. In spontaneous spoken language, it is not always possible to tell whether a clausal unit is embedded within another, because conjunctions also have uses as independent discourse particles and also because two speakers may be involved in the production of a single sentence. Both of these problems challenge analysts who try to identify recursion in conversation.

The data that Laury and Ono present show that clausal recursion is a strictly limited phenomenon in spoken language. Embedding beyond the depth of two is extremely rare, and the upper limit of clausal embedding is four. Embedding of a clause within a clause of the same type, typically used to illustrate recursion in the literature, is a vanishingly rare phenomenon. In fact, as their data show, speakers of Japanese and Finnish do not seem to be constructing complex clause combinations but rather joining clauses together one at a time. In other words, the authors conclude, recursion appears to be *irrelevant* to what actual speakers do. They then suggest that a more obvious characterization of clausal embedding is to simply say that speakers know, for example, how to quote, how to identify and describe referents, and how to give reasons, all in the form of one clause combination at a time. They conclude that the nature of clause combining and the limited extent of clausal embedding in ordinary conversation casts doubt on the status of recursion as a defining feature of human language. Recursion, they say, at least as far as Finnish and Japanese are concerned, may be only a linguist's category, and not supported by the primary form of language. This remark relates to the ques-

tion raised earlier concerning the distinction between the actual workings of language (which, unfortunately cannot be established objectively) and the way that linguists try to model these mechanisms.

Whereas the two previous chapters report on the limited use of recursion in the investigated languages, the chapter by **Stapert and Sakel**, drawing on their own fieldwork data, tests Everett's (2005) claims about Pirahã having no subordinations or other syntactically recursive structures. They consider possible alternatives for languages to express complex thought and compare their findings from Pirahã with discussions in the recent literature (such as the two above-mentioned chapters) on spoken versus written language and formulaic language use. They also consider the possibility that recursive structures could have been borrowed from Portuguese, with which Pirahã is in contact. They argue, finally, that complex ideas can be expressed by other means than syntax, and therefore that syntactic recursion may be common (relative to what we learn from the above-mentioned studies), but not universal in human language.

Mithun examines a range of complement and adverbial clause constructions which could or have been characterized as displaying recursion in three genetically and distinct languages. Examples of older constructions are drawn from Central Alaskan Yup'ik Eskimo. The Yup'ik constructions are pervasive in speech and deeply entrenched in the grammar, signaled morphologically. Their origins can still be detected, however, in nominalized clauses. The adverbial clauses are marked by subordinating suffixes descended from case markers. Somewhat younger embedded constructions can be seen in Khalkha Mongolian. A pervasive complement structure, descended from a quotative construction, is marked by a particle homophonous with a non-finite form of the verb 'say'. This complement construction is no longer restricted to use with utterance verbs like 'say'; it occurs with a range of other verbs as well. Still, it has not yet been extended to commentative verbs ('be sad', 'be significant'), modals ('be able', 'should'), achievements ('manage', 'try'), or phasals ('start', 'finish'). The author also discusses various adverbial clause markers in Khalkha that are descended from case suffixes: locative ('at N', 'when S'), instrumental ('with N', 'as a result of S', 'in order to S'), and ablative ('from N', 'because of S'). Examples of the youngest embedding constructions are drawn from Mohawk. Mithun says that it may seem that complement constructions have not yet arisen in the language: Mohawk speakers use simple sequences of sentences where speakers of other languages would use embedding. She then addresses the important role of prosody, showing that once prosody is taken into account, clear patterns

of embedding are easy to identify. Other young complement constructions include demonstratives or definite articles. Again, a consideration of the prosody shows how they originated and evolved, along pathways different from those usually assumed for complements marked with demonstratives in Germanic languages. Temporal adverbial clauses appear at first to be lacking as well. Mohawk speakers seem to simply add a sentence beginning with a particle 'at the time, now, then', where speakers of other languages would use dependent adverbial clauses. Here once more, prosody shows that they are integrated into larger sentences. Mithun concludes that the variability in space and time calls into question the status of recursion as the basic design feature of human language. It suggests instead that recursive structures are epiphenomenal, the product of combinations of a variety of cognitive processes such as the routinization of frequently-used structure combinations, the reification of events, and the generalization of functions of markers and constructions to ever more abstract contexts. Mithun concludes that recursive structures that occur in human languages are not uniform cross-linguistically, nor are they static within individual languages. This variety indicates, she argues, that recursion may not be the fixed, fundamental, hard-wired property envisioned.

Verhagen sets out to characterize the notion of recursion from an empirical perspective and, in so doing, he shows that the role of 'recursion' is rather overestimated. He distinguishes between two different notions that are related but not identical, and that have played a role in different stages of 20th century theoretical linguistics:

(27) a. 'Different parts of a phrase may be separated by other (indefinitely long) phrases', effectively the notion of 'long distance dependency'.

b. 'The specification of certain phrases requires the application of a rule to its own output'.

He claims that if (and only if) both cases occur in combination we have what computer scientists call 'true recursion' (i.e. center-embedding), which requires a special kind of computational architecture, in order to keep the intermediate results of the calling procedure in memory while the embedded instance is being executed. If situation (a) does not hold, embedded phrases occur at the 'edges' of embedding phrases and processing architecture capable of handling iteration suffices, because special architecture to store and retrieve intermediate results is not required (although their description may still involve a recursive rule).

Using the above distinctions, Verhagen critically examines three phenomena that have been taken as instantiating recursion in the sense of sentential embedding, viz. embedding of adverbial clauses in other adverbial clauses, nonfinite complementation in causative constructions, and long-distance *Wh*-movement (cf. examples (26a–c) respectively):

(28) a. [$_S$ Because our flight turned out to be cancelled [$_S$ when we arrived in Madrid]], . . .
b. He made [$_S$ me understand the situation]
c. Who$_i$ did Mary say [$_S$ that John kissed t_i]

On the basis of actual usage data, Verhagen shows that none of these classic cases actually requires a truly recursive specification. Empirically, a system that uses relatively specific templates is at least indistinguishable from one using general recursion, and is in some respects even more adequate (which has obvious consequences for the issue whether recursion can have been a target of selection). He does acknowledge that recursion is relevant for grammar for some 'pockets' of rather specific phenomena, adding that it may very well have been produced by cultural evolution (involving literacy) rather than genetic evolution.

5. Discussing the need for recursion on formal and functional grounds

The last three mentioned chapters suggest that many apparently recursive constructions may be the result of specific templates (which figure specific lexical items), rather than free-wheeling recursive mechanisms. As mentioned, this raises a question concerning the difference between formal properties of grammars and the languages that they model. In the following five chapters, this issue is discussed from formal and functional perspectives.

Pullum and Scholz start out observing that certain remarks in the linguistics literature over the past few years suggest that some linguists think of *infinitude* (i.e. the infinity of language if thought of as a set of expressions generated by a grammar) as a universal. That is, these linguists, they say, believe that it has been empirically established that there are infinitely many grammatical expressions in human languages, and that we need recursion in grammars in order to account for this. Pullum and Scholz examine the arguments given for the infinitude claim, and show that they depend on an unwarranted assumption: that the only way to

represent syntactic properties is through a generative grammar with a recursive rule system. They then explore some of the reasons why linguists have been so willing to accept language infinitude despite its inadequate support and its lack of linguistic consequences. These authors suggest that the infinitude claim seems to be motivated chiefly by a lingering adherence to the outdated notion that languages should be regarded as sets. It is not motivated by considerations of the creative aspect of language use, or opposition to associationist psychology, or the putative universality of iterable linguistic structure such as recursive embedding or unbounded coordination (which are probably not universal anyway).

Langendoen examines Pullum & Scholz's argument that there has never been an adequate demonstration for the claim that natural languages contain infinitely many expressions, and concludes that they are correct in asserting that the question remains open. He then proposes a method whereby it can be determined at least under certain conditions whether a language has infinitely many expressions, and finally assesses the claim in Postal & Langendoen (1984) that natural languages contain transfinitely many expressions.

As discussed in section 1, Hauser, Chomsky and Fitch (2002) claim that a core property of the human language faculty is recursion and that this property yields discrete infinity of natural languages. On the other hand, recursion is often motivated by the observation that there are infinitely many sentences that should be generated by a finite number of rules. According to **Tiede and Stout** it should be obvious that one cannot pursue both arguments simultaneously, on pain of circularity. The main aim of their chapter is to clarify both conceptually and methodologically the relationship between recursion and infinity in language. They argue that discrete infinity is not derived, but a modeling choice. Furthermore, many arguments, both for recursion and infinity in language, crucially depend on particular grammar formalisms. Thus, care should be taken to distinguish, on the one hand, whether to derive infinity from recursion or the other way around, and, on the other hand, the role of recursion in language in general from the role of recursion in specific grammar formalisms.

Pursuing a similar line of inquiry, **Perfors, Tenenbaum, Gibson and Regier** state that recursion involves an inherent tradeoff between simplicity and goodness–of–fit: a grammar with recursive rules might be simpler than one without, but will predict the sentences in any finite corpus less exactly. As a result, one cannot conclude that any particular grammar or grammatical rule is recursive, given a corpus, without some way to quantify and

calculate this tradeoff in a principled way. They present a Bayesian framework for performing rational inference that enables us to quantitatively evaluate grammars with and without recursive rules and normatively determine which best describe the sentences in a corpus of child-directed spoken English. Their results suggest three main points. First, they suggest that rational principles would favor a grammar with a specific type of recursive rule, even if there are relatively few instances of particular recursively-generated sentences in the input. Second, they suggest that the optimal grammar may occupy a representational middle ground between fully recursive and non-recursive. Finally, their results suggest that the optimal grammar may represent subject NPs distinctly from object NPs.

According to **Harder** functional linguists tend to think that recursion as an issue in linguistics is an artifact of a Chomskyan formalism, i.e. from a functionalist point of view, the mathematical properties of models used to describe languages do not automatically qualify as features of real languages. Like everything else, human languages can be simulated by a formal model, but, as we have seen several times, that does not entail that the properties of the model are also properties of the language. However, at the same time, functional linguists do not dispute that languages like English possess syntactic mechanisms that *can* be formally modeled by recursion. For a functionalist linguist, this then poses the challenge of considering whether recursion has a functional role in language. Recursion, he says, may not be the right way to account for linguistic creativity, but functionalists need to offer their own take on the issue – including the question strikingly raised by Pirahã (cf. Everett 2005), of what the precise relations are between recursion in culture, cognition and language.

6. Evolutionary Perspectives

The HCF paper also addresses the issue of language evolution, a subject that has moved to the center of attention during the last couple of decades, despite Chomsky's earlier pessimism that anything significant could be said about this subject. By proposing that the innate human capacity for language is not a 'richly articulated' mental system (as used to be the case in generative grammar), but a rather minimal system that merely contains a recursive device (in the sense of general recursion; cf. 5), the question of how language came about is considered more manageable by HCF. Human language could have come about abruptly from a simpler

word-based system (allowing one-word utterances only) because the only thing that is needed is to add a recursive device (cf. Reuland 2009).

Hornstein (2009) suggests an even more specific mechanism that made recursion possible: endocentricity or headedness, or what he calls 'labeling'. Turning back to the rules in (6), while X and Y *may* be identical (which produces specific recursion), it is usually claimed that X and Z *must* be identical, which is to say that the category label of a complex syntactic object is projected from one of the daughters, called its *head*. If a complex word is a noun, one of its daughters must be a noun as well (in derivational morphology this would be a noun-making affix, while in compounds it would be simplex or complex word), and if a phrase is a noun phrase it must contain a word of the category noun. According to Hornstein (2009: 59–60) it is the emergence of this specific labeling convention (i.e. projection from the head) which kick started recursion in the evolution of language:

(29) a. XPhrase ⇒ YPhrase X (e.g., NP ⇒ APN)
b. XWord ⇒ YWord X (e.g., N ⇒ VN_{aff})

Indeed, it would seem that this rule meets the criterion of being recursive on the understanding that the label of a head and the label of its mother node are *strictly* identical, which means that we must ignore or eliminate the difference between phrase labels (XP) and word labels (X) and thus replace (28a) by (28b):

(30) a. XPhrase ⇒ YPhrase X
b. X ⇒ YX (e.g., N ⇒ AN)

However, by locating recursion in this labeling convention, as Hornstein does, the recursive symbol on the right side of the arrow is the *head* of the expansion, whereas the usual approach, while accepting the idea of headedness, locates recursion in the *dependent* (or *complement*) to the head:

(31) a. VP ⇒ VPV
b. V ⇒ V_1V_2

If (31b) is the counterpart of (31a), by virtue of eliminating the difference between XP and X, V_2 would be the head, while V_1 would make the rule recursive (because of its identity to the V to the left of the arrow). In conclusion, it is not clear to me how Hornstein can locate the source of recursion in the head labeling convention, i.e. in endocentricity, if recursion in

the usual sense results from identity between the symbol on the left and the *non-head* symbol on the right of the arrow.

Taking this one step further we might say that Hornstein's idea that headedness entails recursion is correct after all, in the sense that endocentricity leads to what I will call *recursion following from adjunction*. Indeed, when linguists speak of adjunction they refer to a situation in which a head is expanded with a dependent with the result being a category that is identical to category of the head. Normally this means that the resulting category has the same category and the same complexity as the head. In fact, the rule in (19) (NP ⇒ NP + S) was a rule of precisely this sort. Hornstein seems to include the case in which the head is simplex (i.e. lexical category), while the result is phrasal. But by ignoring this difference one might say, then, that headedness entails recursion following from adjunction. However, this kind of recursion differs from the 'prototypical' case in which a combination has the same category status as the dependent, which I will call *recursion following from subjunction*. It remains unclear how the former type of recursion automatically leads to the latter type.

Whatever the merit of Hornstein's suggestion, there can be no doubt that the step from one word utterances to multiword utterances with hierarchical structure (perhaps mediated by a two-word 'proto-language') was a crucial step in the development of human language, but it remains questionable whether this is the only property that sets human language apart from other communication systems (cf. Jackendoff and Pinker 2005). The evolutionary angle is examined in the following four contributions.

Kinsella evaluates the HCF claim that recursion is the one property which sets human linguistic abilities apart from any other system of communication or cognition which she considers to be fundamentally flawed. Like Jackendoff and Pinker (2005) she argues that, first, properties of language independent of its recursive nature are unique to the system and, second, recursion is exhibited in domains outside human language. Thirdly, she argues that language works equally well without recursion.

Progovac focuses her attention on what she calls *a small clause grammar* which co-exists, in English, with *a sentential grammar*. The latter is a robust system of functional projections and structural relationships (tense, case checking, complementizers), while the former does without any such mechanisms, and without a possibility for recursion/embedding. She proposes that this small clause grammar is a vestige/"living fossil" of a previous stage of morpho-syntax which utilized no functional categories (which she claims, are necessary for embedding). Her conclusion is that a relevant functional projection/category is necessary to facilitate embedding. She

argues that if a human grammar with Merge, but without recursion, is possible, then recursion cannot be the defining property of human language, and neither can Merge alone be responsible for all its recursive power (contra the hypothesis in Hauser, Chomsky, and Fitch 2002). This perspective opens up a new way of looking at some puzzling constraints in syntax, including Subjacency.

Rogers and Hauser discuss acoustic pattern recognition experiments, often called artificial language learning experiments, which, they claim, hold the promise of providing a method for dissecting the ontogenetic and evolutionary building blocks of the language faculty. In particular, by studying the capacity to acquire specific fragments of linguistic computation in human infants and nonhuman animals, it is possible to determine which psychological processes are available to the developmentally immature human learner and which to humans' evolutionarily ancestors. They specifically explore the formal mathematical structure of these experiments and develop criteria for their design and interpretation based on the Sub-Regular Hierarchy, a hierarchy of complexity classes which correspond to a hierarchy of cognitive capabilities that are relevant to any faculty that processes acoustic stimuli solely as sequences of events.

7. Recursion and the Lexicon

In most articles, specific recursion is treated as a property of syntactic, i.e. sentence-level expressions. The following two articles examine the role of recursion with reference to the lexicon, although the authors take very different perspectives and arrive at seemingly contradictory conclusions.

Koster defends a lexicalist approach to recursion in syntax. In a lexicalist framework, syntactic base structures are no longer generated independently of the lexicon but are seen as projections from lexical elements. Chomsky (1981, 31–32) discusses the *redundancy problem* that arises with lexicon-independent rules: these rules would introduce properties as hierarchical phrase structure organization and recursion, while these elements *also* exist independently, namely as the projection properties of lexical items. Surprisingly, Koster says, Minimalism reintroduced lexicon-independent structure generation in the form of Merge. This, then, brings back the redundancy problem. As a remedy, Koster proposes to maintain a version of X-bar theory, in which structure-building (with hierarchical organization and recursion) is seen as filling the slots that exist as a matter of lexical projection. Syntactic computation is done on the basis of these lexical-

cartographic structures and involves the selective, strictly local sharing of properties: by sisters (horizontal) and by daughters and mothers (vertical). By iteration of vertical property sharing (percolation) and in combination with horizontal property sharing, most forms of syntactic construal (including "movement") can be accounted for. In the framework proposed by Koster, recursive Merge is not a rule of grammar, but a characterization of the abstract background capacity that humans built into language by inventing a complex lexicon, as a matter of free, agentive application. In that respect, he claims, language is part of human culture and differs from biological organology, which, clearly, involves non-agentive functionality.

Juarros-Daussa's starting point is the basic fact of argument structure that verbs cannot take more than three core arguments – more precisely, one subject, or *external* argument, and two objects, or *internal* arguments, as in the English verb *give* (32a). Introducing a conceivable additional participant without the help of a lexical preposition (such as *for* in (32c) below), which contributes its own argument-taking abilities, results in ungrammaticality (32b):

(32) a. [The LinguistList] gave [nice prizes] [to the winners of the challenge]

b.* [The LinguistList] gave [nice prizes] [to the winners] [(to) the students]

c. [The LinguistList] gave [nice prizes] [to the winners] [for the students]

In her chapter, the above observation is formulated as the *Two-Argument Restriction* (TAR): "A single predicate can have at most two internal arguments and one external." The author claims that the TAR is an *unrestricted universal* (in the sense of Croft 1990) and shows that valency-increasing operations such as applicative and causative constructions, which present an apparent challenge, do not violate the TAR. She further argues that, since there is no known processing reason not to lexically associate more than three (two) participants to a predicate, the TAR is syntactic in nature, and it is one of a family of architectural constraints that determine and limit possible attainable languages (in this case possible argument structures). Following this idea, she shows that the framework of lexical syntax put forth by Hale and Keyser (2002) is especially suited to derive the TAR. In her proposal, deriving the TAR crucially involves negating the existence of a recursive function in the domain of argument structure.

8. Recursion and Morphology

As traditionally understood, complex words display direct or indirect specific recursion. This can be most easily demonstrated in the domain of compounding. Consider the following compound rules in English (taken from van der Hulst 2008):

(33) **Compounding**

N ⇒ N N	arm - chair
N ⇒ A N	green - house
N ⇒ V N	jump suit
V ⇒ V V	break dance
V ⇒ N V	steam roll
V ⇒ A V	white wash
A ⇒ A A	red hot
A ⇒ N A	nation wide
A ⇒ V A	-

In each of the three blocks of rules, the first one meets the criterion of being recursive: the dependent is of the same type as the whole construction. In the area of derivation we also attest recursion:

(34) a. ***Suffixation***

N ⇒ N N^{aff}	*friend - ship, child - hood, host - ess, hand - ful*
N ⇒ A N^{aff}	*tall - ness, free - dom, loyal - ist, real - ism*
N ⇒ V N^{aff}	*sing - er, employ - ee, grow - th, inform - ant*
V ⇒ V V^{aff}	-
V ⇒ N V^{aff}	*victim - ize, beauti - fy*
V ⇒ A V^{aff}	*black - en*
A ⇒ A A^{aff}	*green - ish*
A ⇒ N A^{aff}	*boy - ish, wood - en, nation - al, pain - ful*
A ⇒ V A^{aff}	*read - able, help - ful, harm - less, act - ive*

b. **Prefixation**

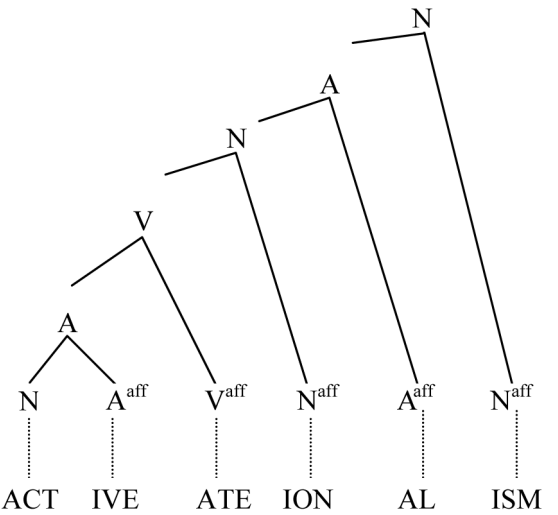
N ⇒ N^{aff} N	*anti - war, ex - president, super - structure*
N ⇒ N^{aff} V	-
N ⇒ N^{aff} A	-

$V \Rightarrow V^{aff}\ V$ *un - do, re - read, mis - align*
$V \Rightarrow V^{aff}\ N$ *en - slave, be - witch*
$V \Rightarrow V^{aff}\ A$ *be - little*

$A \Rightarrow A^{aff}\ A$ *un - fair, dis - loyal*
$A \Rightarrow A^{aff}\ N$ -
$A \Rightarrow A^{aff}\ V$ -

Recursion results not only from rules that are themselves recursive but also from rule sets that form recursive chains which produce indirect recursion:

(35)



If even English, with its modest morphology, displays specific recursion, it is to be expected that in polysynthetic languages recursion will play an even greater role in the morphology; cf. Mithun, this volume.

Lander and Letuchiy present a survey of various morphological phenomena in Adyghe, a highly polysynthetic language of the Northwest Caucasian family, such as multiple applicatives, multiple propositional operators (e.g., tense markers), and double causatives that all seemingly instantiate recursion. It is argued, however, that the corresponding derivations differ in what concerns their 'recursability', i.e., their inclination to recursion. Moreover, they propose that the degree to which a derivation is 'recursable' correlates with the extent to which a derivation affects the meaning of a stem and the structure of the verb. Since no apparent syntactic restrictions of this kind are found, this suggests that despite the

existence of morphological recursion, the latter is still somewhat more constrained than recursion in syntax.

9. Recursion and phonology

It is quite common to read that phonology is not recursive. To illustrate this point it is often mentioned that, for example, we do not find 'syllables inside syllables'; cf. the quote from Pinker and Jackendoff given earlier. On the other hand, Ladd (1986, 1996) argues that higher-level prosodic structure allows (limited) recursion. I also refer to Wagner (2005, 2007a, 2007b) for extensive discussion of these matters, again with specific reference to higher levels of prosodic organization. Since phonology is somewhat underrepresented in this volume, I included a chapter on this subject in this volume. In this chapter **van der Hulst** first discusses recursion at lower levels of organization (syllable and foot) showing, contrary to popular belief, that it is possible to think of codas as 'syllables within syllables' and, also, once this move is made, to reanalyze feet in terms of recursive syllable structure. Second, he turns to recursion at higher prosodic levels reviewing some of the above-mentioned literature. One central issue that emerges from this discussion is that the kind of data that suggest recursion at higher levels could also be taken as supporting the idea that phonological rules (for example, rules for phrasal accentuation) make *direct reference* to the recursive syntactic structure, in which case we have no argument for recursion in the prosodic structure as such (cf. Wagner 2007a, 2007b). A second central theme regards the fact that the recursion of prosodic structure itself, if such can de demonstrated to exist, would be caused by (a) adjunction of 'stray' units (creating one level of recursion) and (b) by the 'desire' to make prosodic structure isomorphic to the syntactic structure which may take the depth of prosodic recursion further. However, in this latter case, as has been argued in Giegerich (1985), recursive structure often tends to be replaced by a flatter structure which is more rhythmic. It would seem, then, that rhythmic forces suppress excessive recursion in phonology or that phonological recursion and rhythm occur at different levels of representation.

Hunyadi introduces the *principle of tonal continuity* to account for the continuous tonal phrasing of discontinuous structures with nested embedding and suggests that what underlies this cognitive computational process is the *bookmark effect*. He shows that the computational difference between nested recursion and iteration correlates with their prosodic difference, whereas tail recursion and iteration (which are computationally indistin-

guishable) also have a similar prosodic realization. Through grouping experiments with (a) abstract visual elements, (b) abstract prosodic elements and (c) actual linguistic utterances Hunyadi shows that speakers use temporal and/or tonal variation to indicate various kinds of grouping and he attributed the underlying principles to more general cognitive strategies because, apparently, they play a role outside language. For temporal variation, recursive embedding is denoted by pre-boundary shortening and de-embedding by pre-boundary lengthening so that for each embedded phrase, the pause preceding it is shorter than the pause following it and that with each level of recursive embedding these respective pauses decrease at the point of embedding and increase at the point of de-embedding. For tonal variation, recursive embedding is denoted by the pre-boundary lowering of the tone and de-embedding by the pre-boundary raising of the tone so that with each level of recursive embedding a given phrase is embedded at a pitch level lower than the previous one.

Hunyadi's paper, specifically his discussion of the principle of tonal continuity relates to Mithun's paper in that this principle demonstrates that intonation can be used as a mechanism to encode embedding and this, one might argue, does not necessarily presuppose a syntactic embedding mechanism. In other words, semantic center-embedding can perhaps be encoded in terms of intonation alone, which suggests, in line with several other chapters that syntactic recursion, or, specifically, syntactic center-embedding is not the only grammatical device that can be used to encode semantic center-embedding.

A final remark about intonation. Intonation is not 'phonology'. The intonational tune is not merely part of the phonological side of linguistic expressions. Intonational tunes are the product of an intonational grammar which produces intonational expressions that have morphotactic, semantic and phonotactic components; cf. Gussenhoven (1984). As such, the question can be raised whether the intonation grammar displays recursion in its semantic, morphotactic or phonotactic component. I will not explore that issue here.

10. Recursion outside Syntax

Finally, the question arises as to the language-uniqueness of recursion. It has been acknowledged that other human cognitive systems also display recursion. In this connection, some mention the numerical system. Chomsky (2005: 6), however, suggests that the numerical system may be the same recursive merge mechanism that is responsible for linguistic expres-