# Recursion in language: a new approach

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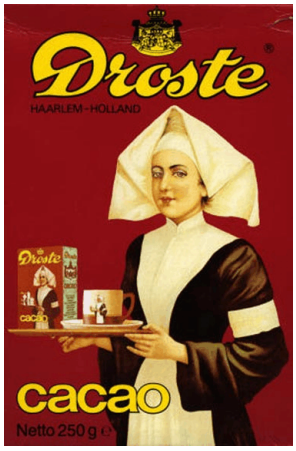
1. A procedure is recursive if part of it involves running the entire procedure anew. The output of such a procedure is also called recursive. For example, the procedure that draws the famous Droste can picture in (1) at some point involves calling the very same procedure, in order to draw that can *in* the picture.

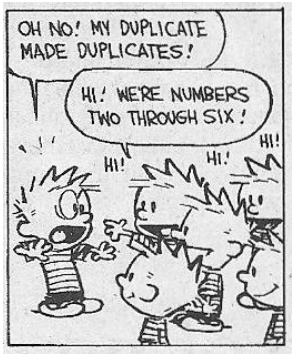
(1)




However, one cannot tell that an object is recursive by simply looking at it: one has to know by what procedure it was derived. For example, the picture in (1) could have been generated in a nonrecursive way (and it probably was), for instance by assigning a color to each pixel.

In another example, consider the situation in (2), from the comic strip 'Calvin and Hobbes', where the boy Calvin finds himself surrounded by five duplicates of himself.

(2)




As Calvin exclaims, the procedure bringing this situation about was recursive: Calvin made a duplicate of himself, and the duplicate proceeded to make a duplicate of *him*self, etc. However, Calvin could have created five duplicates by simply repeating the duplication process five times, yielding an *iterative* rather than a *recursive* procedure.

In language, it is commonly taken for granted that structures involving some kind of

embedding are recursive. Typical examples are in (3):

(3) a. John thinks that Mary said that it was raining
b. the height of the letters on the cover of reports from the government

The structures in (3) are recursive if they are generated by a recursive procedure, such as the rewrite rules of preminimalist generative grammar. The procedure generating (3a) may be paraphrased as in (4), showing recursion in that to interpret 'clause' in (4b), one must run (4a) again.

(4) a. clause = subject + predicate
b. predicate = verb + clause

Similarly with the procedure in (5) generating (3b):

(5) a. determiner phrase = determiner + noun phrase
b. noun phrase = noun + preposition phrase
c. preposition phrase = preposition + determiner phrase

For this reason, embedding is taken to signal recursion, underlying much of the debate between Everett (2005, 2009) and Nevins et al. (2009) on recursion as a defining property of natural language. It will be recalled that Everett (2005) observed that the Amazonian language Pirahã lacks embedding, which was contested by Nevins et al. (2009) but upheld by Everett (2009). In the original (2005) article, the connection of embedding and recursion was not made (except in a comment by Michael Tomasello), but in his 2009 reply to Nevins et al. (2009), the absence of recursion in the grammar of Pirahã was made the centerpiece of Everett's claim. At the background of this discussion is the hypothesis of Hauser et al. (2002) that recursion is the defining property of the faculty of language.

Meanwhile it should be clear that the model of grammar as understood in current minimalism no longer involves rewrite rules of the type in (4)/(5). Instead, structure is created by a single operation Merge which Chomsky (1995) defines as taking two elements and combining them in a set:

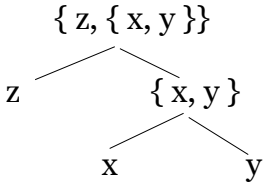
(6) Merge
a. select *x*
b. select *y*
c. create { *x*, *y* }

Merge may be (re)written as a rewrite rule:

(7) Merge
x, y = { x, y }

It is (mostly implicitly) understood that the next time Merge runs, it takes the output of the previous run as part of its input. Thus, *x* or *y* on the left hand side in (7) may be { x, y }, yielding recursion. If the next run combines { x, y } with *z*, the structure in (8) results:

(8)




(8) is a familiar binary branching phrase structure (where { x, y } may be written as the projection of *x*, *X'*, and { z, {x, y }} as the maximal projection *XP*). Such molecular structures are arguably the building blocks of all natural language phrases (including those in (3)), suggesting that every phrase consisting of more than two elements is the output of a recursive procedure (Nevins et al. 2009:366).

However, just like Calvin's band of duplicates, the phrase structure in (8) can be generated by an iterative procedure as well. For instance, we may think of the structure building process as a transfer procedure, moving elements from a resource (the lexicon, or a subset of the lexicon, or some other collection of elements, called *Numeration* in Chomsky 1995) to a workspace (the structure under construction). This procedure is spelled out in (9):

(9) Transfer
   a. Move *y* yielding { y }
   b. Move *x* yielding { x, y }
   c. Move *z* yielding { z { x, y }}

Transfer is clearly iterative, and yet it yields the same structures as the recursive procedure in (8). It follows that we cannot decide that a language (or natural language) 'is recursive' by simply looking at its structures. We have to know about the procedure (see also Everett 2009:438).

2. There is ample reason to believe that the procedure generating clauses must be simple. Constituency tests generally yield the result that structures are binary branching, and structure-to-order conversion is not random but more or less automatic. This suggests a simple, stepwise procedure involving no more than two elements in each step, creating structure incrementally in a way that can easily be tracked by interpretive components of the mind/brain.

I have argued elsewhere that transfer (or a similar procedure) is simpler than Merge, in that it identifies in each step a single element to be manipulated (transfered), while keeping the destination of transfer constant throughout the derivation. This yields binary branching structures with asymmetric sister pairs, essentially a nest of ordered pairs which can be linearized straightforwardly (along the lines of Fortuny 2008; see Zwart to appear a, b).

One can think of transfer as an iterative procedure selecting (or identifiying) one element at a time from the Numeration, creating a record of elements identified. As argued in Zwart (to appear b), this procedure can be viewed as working from the top down, splitting the Numeration in an element identified and a residu set. For example, (8) can be derived by starting from the Numeration in (10), via the steps in (11).

(10) Numeration = { x, y, z }

(11) Transfer
   a. split off *z* yielding ⟨ z, { x, y } ⟩
   b. split off *x* yielding ⟨ z, ⟨ x, { y } ⟩⟩
   c. split off *y* yielding ⟨ z, ⟨ x, ⟨ y , { ∅ } ⟩⟩⟩

It is easy to see that transfer can yield embedding structures without recursion (see also Christiansen 1994, referred to in Parker 2006:184). For example, (3a) can be derived from the Numeration in (12) by iterative splitting:

(12) Numeration = { John, thinks, that, Mary, said, that, it, was, raining }

Embedding, then, does not betray recursion if the structure building procedure is as simple as suggested here.

However, it is clear that not all sequences can be derived by iteratively splitting of the elements in the sequence from a Numeration containing them. Essentially, every complex noncomplement (e.g. a subject) must be included in the Numeration as an atom. To see this, consider the derivation of (13).

(13) The man kicked the ball

Constituency tests show that *the man* and *kicked the ball* in (13) are constituents. For example, *kick the ball* can be isolated in VP-fronting constructions like (14).

(14) The man said he would kick the ball, and KICK THE BALL he did

Likewise, *the man* can be isolated in the backgrounding construction in (15).

(15) He kicked the ball, THE MAN

But the sequence *man kick(ed) the ball* cannot be identified as a constituent by any known test.

The procedure generating (13), then, must yield a structure in which *the* and *man* are joined together before *the man* is joined with the rest of the clause. Iterative transfer starting from the Numeration in (16) could not yield this result, as can be seen after the first application of split in (17a).

(16) Numeration = { the, man, kicked, the ball }

(17) Transfer
   a. split off *the* yielding ⟨ the, { man, kicked, the ball } ⟩

It must be, then, that *the man* is included as a single item in the Numeration underlying (13):

(18) Numeration = { [the man], kicked, the ball }

Transfer then yields the correct result in terms of constituent structure:

(19) Transfer
a. split off *the man* yielding ⟨ [the man], { kicked, the, ball } ⟩

It follows that *the man* must have been created in a separate derivation (or derivation layer), with the Numeration in (20) and the iterative transfer procedure in (21).

(20) Numeration = { the, man }

(21) Transfer
a. split off *the* yielding ⟨ the, {man } ⟩
b. split off *man* yielding ⟨ the, ⟨ man, { ∅ } ⟩⟩

The output of this derivation is included in the Numeration for the next derivation (i.e. (18)).

It should be clear now that the derivation as a whole, including the layers (20)/(21) and (18)/(19), is recursive: the output of the procedure (20)/(21) is part of the input (the Numeration) of the same procedure in (18)/(19). If this is the correct approach, recursion is not evidenced (necessarily) by embedding, but it is evidenced (necessarily) by left branch embedding (sometimes called 'left-tail recursion').

3. Recursion in language is also typically illustrated by examples like (22), involving center-embedding.

(22) the dog the cat bit barked

Here, *the cat bit* is a restrictive relative clause modifying *the dog*. The constituency of (22) is as indicated in (23):

(23) [ [ the dog [ the cat bit ] ] barked ]

In (22)/(23), we again see a complex subject (*the dog the cat bit*) which must have been derived in a separate derivation layer. The structure of (22)/(23), then, is recursive already for the same reason that the structure of (13) is. Center-embedding reduces to left branch embedding (and 'nested recursion' is in a natural class with 'left-tail recursion', if we are right).

It has been observed that center-embedding cannot be performed indefinitely, unlike right branch embedding (Yngve 1961). Consider the triple embedding in (24), contrasting markedly with the triple embedding in (3a).

(24) [ [ the dog [ the cat [ the man kicked ] bit ] ] barked ]

It seems, then, that recursion (as understood here) comes with a cost (perhaps in memory load, as Yngve suggested). Much better again are (25) and (26):

(25) the dog that the cat bit that the man kicked barked

(26) the dog that bit the man that kicked the cat barked

The difference may be accounted for by the fact that (25) and (26) contain fewer derivation layers (due to the right branch embedding) and hence less recursion.

4. If recursion in language is correctly defined as the interaction between derivation layers, it is easy to identify other phenomena that betray recursion in this sense. Assuming the model of grammar entertained in minimalism, each derivation (sequence of operations Merge) feeds the interface components dealing with sound and meaning, and hence we may expect the output of a derivation layer to show idiosyncratic sound/meaning properties. Moreover, we expect the output of a separate derivation layer to behave as an atom in the context of the next derivation layer: constituents of the output of a separate derivation are not themselves in the numeration for the next derivation, and therefore cannot be merged individually in the context of that next derivation. This, I believe, derives a wide range of opacity effects, as first observed in Toyoshima (1997).

Among the interface effects affecting derivation layer outputs are (cf. Zwart to appear b):

(27) a. morphological effects (incorporation, conflation, fusion)
b. atomization (opacity)
c. idiosyncratic meaning (idioms)
d. linearization effects (idiosyncratic order, template effects)
e. categorization effects (reanalysis)

The effects in (27) all show a mix of syntactic and lexical properties. For instance, complex verbs (e.g. involving a transitivizing morpheme, possibly covert, like the 'little v' of Chomsky 1995) are clearly structured, but also clearly lexical (in obeying Lexical Integrity, for instance). The mixed properties are accounted for if such elements are created in a separate derivation layer, and pass through the interface components before being enlisted in the Numeration for the next derivation layer. If this is the correct approach, then structured lexical items all betray recursion in the sense understood here.

In view of this, I would like to define 'lexical' in relative terms, i.e. in the context of a derivation layer, as in (28).

(28) Lexical
*x* is a lexical item for derivation D of numeration N if *x* is included in N as a single item

(Note that under this definition, complex subjects are lexical items.)

5. The question now arises, to what extent does a language like Pirahã show signs of recursion in the sense of derivation layering? I will try to answer the question, using uncontested data from Everett (1986), by looking for a) complex subjects and b) structured lexical items (in the sense of (28)) showing interface effects.

5.1 I believe it is uncontested that Pirahã does have phrases, and therefore, if Pirahã lacked recursion (in our sense), we would expect phrases to show up only in complement position, not in subject or adjunct position. Indeed, the large majority of the subjects in the examples of Everett (1986) appear to be single word items (though they may be nominalizations or

compounds, for which see below). But even so, several examples of complex subjects can be found in the examples (numbers refer to the example numbers in Everett 1986):

(29) Complex subjects in Pirahã (not including nominalizations/compounds)

a. **xipoógi hoáoíi** hi xaagá (22)
Xipoógi shotgun 3 be
'That is Xipoógi's shotgun.'

b. **xoogiái hi xapisí** biga aí big-á (43)
Xoogiái 3 arm thick be thick-EMPH
'Xoogiái's arm is thick (i.e. strong), very strong.'

c. **giopaí gáihi** kapióxio xigiábií (85)
dog that other like
'That dog looks like another (dog).'

d. **ti xahaigí** gáihi (196a)
1 brother that
'That (one) is my brother.'

e. **kaoí xahaigí** gáihi (196b)
who brother that
'Whose brother is that?'

f. **baaí xaíbaí** pii ap-ái-p-i pii bo-ó
wild pig many water enter-ATELIC-IMPF-PROX water up-LOC

gai kob-á (277)
DEM see-REM

'A herd of pigs is entering the water upriver, look!'

g. **xoogiái hi go-ó hoasígikoí bíib-i híx** hoasígikoí
Xoogiái 3 WH-OBL lead shot send-PROX C lead shot

koab-áo-b-í-i (282)
run out-TELIC-PERF-PROX-EVID

'The lead shot which Xoogiái sent ran out.'

Of these, (29a) and (29d/e) are copular constructions, which might allow another analysis in which the boldface noun phrase is a predicate. I have no idea about the plausibility of either analysis. Everett (2009:419) comments on the copula-less type in (29d) that it is not a clause but just a string of nouns. But this does not affect the argument, unless the string looks like (30a) rather than (30b).

(30) a. me, brother, that

b. [my brother], that

If (30b), then, assuming iterative merge and layered derivations, *my brother* must still be the output of a separate derivation.

Example (29g) involves a relative clause where it looks like the boldface material is not actually the subject, but a preposed topic, perhaps juxtaposed to the main clause. In that case the boldface material would constitute a complex adjunct, which would have to be the output of a separate derivation under the assumptions entertained here.

5.2 Pirahã verbal morphology is fairly complex, and described in Everett (1986:288-289) as templatic, featuring 18 slots following the verb root. None of these slots are occupied by inflectional morphemes. The categories represented include aspect, negation, interrogativity, deixis, mood, but not tense. The complete template as proposed by Everett (1986) is in (31).

(31) Pirahã verbal template (all following the root)

| | | | | | |
|---|---|---|---|---|---|
| 1. | incorporation | 7. | continuative | 13. | frustrative |
| 2. | duration | 8. | interrogative | 14. | intensive |
| 3. | telicity | 9. | ingressive | 15. | emphatic |
| 4. | perfectivity | 10. | deictic | 16. | complementizer/nominalizer |
| 5. | desiderative | 11. | iterative | 17. | evidential |
| 6. | negation | 12. | certainty | 18. | result |

The first slot behind the root is reserved for incorporation (mainly of verb roots), "an extremely productive method of forming new verbs" (Everett 1986:300-301).

Examples of complex verbs derived via incorporation are:

(32) Pirahã incorporation

a. xab op (388a)
turn go
'return, arrive'

b. xiga hoag (388b)
take come
'bring'

c. xig ab op (388c)
take turn go
'bring back'

As Everett (1986:301) notes, the complex verb is treated as a single unit: neither root can take any affixes, and "suffixes are added to the entire stem as one element". I take this to entail that the incorporated verbs in Pirahã are prototypical structured lexical items as discussed above, i.e. outputs of separate derivation layers.

The etymology of the affixes is not generally elucidated in Everett (1986), but in a few cases he notes that the verbal suffixes are grammaticalized lexical items. For example, the evidential suffix *-xáagahá* 'OBSERVATION' is analysed as involving *xaagá* 'be' and *-há*

'COMPLETE CERTAINTY' (Everett 1986:298).

(33) *-xáagahá* < *xaagá* + *-há*
OBSERVATION be COMPLETE CERTAINTY

This suggests that the verbal complex is the result of conflation as discussed in Hale and Keyser (2002), a typical syntactic process creating lexical items.

The complementizer/nominalizer slot 17 in (31) is occupied by *-sai*, a very productive morpheme for nominalizing verb phrases (Everett 1986:277f) (there is also another nominalizer, *si*). One of its uses is quotative, affixed to a verb of saying, suggesting that it may be an embedding complementizer (cf. Nevins et al. 2009:382).

(34) ti gái-sai kó'oí hi kaháp-ií (Everett 2005:629)
1 say-NOM Kó'oi 3 leave-INTENTION
'I said that Kó'oí intends to leave.'

But Everett (2009:418) takes *-sai* to be a marker of old information, allowing a juxtaposition rather than subordination analysis of the type in (34), where the first clause represents information that is familiar from the discourse setting (presumably akin to backgrounded quotatives in English).

Far more important to the discussion at hand, it seems to me, is the observation that *sai* turns verb phrases into nouns, the kind of process that betrays derivation layering (27e). Examples abound:

(35) Pirahã nominalization

a. kahaí kai-sai (80b)
arrow make-NOM 'arrow making, arrow maker'

b. **xií** **kai-sai** hiaba (200)
thing make-NOM NEG 'this is not a factory'

c. agaoa kait-i-sai (243)
canoe bore-LINK-NOM 'canoe-boring-thing'

d. **tiobáhai** **hóoi** **ai-sai** xabahíoxoi (262)
child bow make-NOM incorrect
'Children's bow making is incorrect.'

e. **ko** **kab-i-si** baósaápisi bag-áo-b-á-há (280)
eye NEG-LINK-NOM hammock sell-TELIC-PERF-DIST-EVID
'The man without eyes (blind one) sold the hammock.'

f. gahió **pi-ó** **xabaip-i-sai** (288)
airplane water-LOC sit-LINK-NOM 'hydroplane'

In a layered derivation approach, nominalizations are perfectly regular syntactic constructions, merged with a nominalizing morpheme, and then turned over to the

interfaces, acquiring idiosyncratic sound/meaning properties. At the interface, the output receives a new categorial feature (N), not transparently derived from any of its constituent parts. The resulting unit can be included as a single item in the numeration for a next derivation layer.

In this context, it is important to note that the nominalizing process is instrumental in creating Pirahã names:

(36) "All names for people are derived from verbal constructions, animal names, nominal phrases, etc. In about 90% of these cases, *-si* occurs optionally in morpheme final position, as though marking a change in the basic reference or function." (Everett 1986: 279-280)

A final category that suggests derivation layering in the grammar of Pirahã involves compounds. Everett (1986) lists numerous compounds, but Everett (2009:423-424) appears to argue that these are not really compounds, admitting that:

(37) "If there were compounding in Pirahã, this would be clear evidence for recursion." (Everett 2009:423)

Let us first look at the examples:

(38) Compounds in Pirahã

a. **xagí gahióo** xogií ái-xi-xi pii xigiábií (86)
path airplane big be-EMPH-EMPH water like
'The **airstrip** is big, like a river.'

b. xogaogií < xogaí + ogií (389)
big field field big

c. xabagisoixaoxoisai < xabagi + soixaoxoisai (477)
saw toucan beak

d. xapaítoii < xapaí + toii (478)
ladder foot handle

e. pigáía < pi + gáía (481)
scissors thorn crooked

f. kaogiái < kao + ogiái (482)
[kind of bass] mouth big

These all seem clear cases of compounds, in most cases acquiring the idiosyncratic (noncompositional or metaphoric) meaning suggestive of derivation layering.

Everett (1986:322) describes his grounds for classifying formations like those in (38) as compounds as semantic: the noncompositional meaning suggests they are lexical items rather than phrases. In Everett (2009:423-424), Everett withdraws the semantic argument and details the prosodic properties of the formations in (38), suggesting to him that they

are not compounds. With the remarks of Everett (1986:322) (see (39)) in mind, we may conclude that he considers (38) not to involve compounds but (syntactic) phrases.

(39) "The criterion to classify the examples to follow as compound words rather than merely phrasal constructions is semantic." (Everett 1986:322)

In the layered derivations approach, there is no fundamental distinction between 'compound words' and 'phrasal constructions'. What is relevant is a) the complexity of the string (suggesting derivation output status), and b) its behavior as a single item in the context of a (subsequent) derivation. The idiosyncratic meaning merely provides an additional argument for these elements' derivational history, regardless their status as words or phrases.

In this context we may also point to complex locatives in Pirahã, suggestive of the kind of fusion that we expect to occur between derivation layers (cf. (27a)).

(40) Complex locatives in Pirahã (326)

| | | |
|---|---|---|
| a. | xoí | 'jungle' |
| b. | xo-ó | 'in the jungle' |
| c. | xo-ó-xio | 'into the jungle' |

6. In conclusion, if recursion is identified in terms of derivation layering, as proposed here, then it seems clear that the grammar of Pirahã is recursive. Both complex subjects and complex lexical items are attested, some in average quantity, some in abundance.

This raises the further question what the observations in Everett (2005), substantiated in (2009), about the absence of embedding imply. Clearly, the wide-ranging implications having to do with the nature of the faculty of language vanish, but the original conclusions of Everett (2005) were considerably less bold and may still be valuable. One suggestion to make, within the model of grammar considered here, is that while interaction among derivations is unaffected by whatever cultural constraints are at play, the size of the Numeration is. Recall from section 2 that embedding structures like (3) can be derived by iterated Merge, starting from a large enough Numeration. Perhaps the 'immediacy of experience principle' that Everett (2005) suggested to capture the cultural constraints on Pirahã grammar (and cognition) constrains the Numeration in ways that virtually preclude ordinary right branch embedding.

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