Limitations on Embedding in Coordinate Structures

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Coordinate structures have traditionally been analyzed as having no internal structure other than the sequencing of their members.* In particular, the possibility that the members of coordinate structures may themselves be coordinate structures has not been widely recognized. Those who have recognized the possibility of such embedding of coordinate structures have assumed that there are no limits on the depth of such embedding, just as there are no limits on the depth of embedding in subordinate structures. However, coordinate-structure embedding in English occurs only in order to prevent coordinate structures from containing distinct connectives (e.g. *and* and *or*), distinct junctures (breaks) between members, and sequences of members in which the first is introduced by a connective while the second is not. In order to prevent these conditions from arising, the depth of coordinate-structure embedding does not have to exceed 2. This limitation on coordinate-structure embedding must be dealt with by the grammars of natural languages; it is not simply a performance limitation. Standard generative mechanisms (finite-state, phrase-structure, and transformational grammars, including recently proposed analyses of coordinate structures based on the Minimalist Program) do not provide an adequate account of this limitation. On the other hand, a theory of constraint satisfaction such as Optimality Theory, in which ranked constraints select the optimally structured outputs for given inputs made up of members, connectives and junctures, does do so. A detailed Optimality Theoretic analysis of coordinate structures in English is proposed which accounts for the limitation on coordinate-structure embedding, as well as several other properties of those structures, and of their interactions with subordinate constructions.

1. Coordinate Structures

Coordinate structures (henceforth CSs) are among the most basic of all grammatical structures.[1] Nevertheless a number of their properties, both linguistic and psycholinguistic, are not well understood. This paper examines one of these properties, the embedding (as defined below) of coordinate structures as members of larger ones. I consider the limitations on such embedding and conclude that they are part of grammar, not matters of linguistic performance, and propose an account of these limitations using Optimality Theory (Prince & Smolensky 1993, Archangeli & Langendoen 1997).

Every CS is made up of two or more constituents called 'members' (Bloomfield 1933: 195); and a CS is typically a constituent of the same type as its members.[2] For example, the CS highlighted in (1)a is a noun phrase (NP) with six member NPs. In (1)b, there are three CSs, one analyzed as a noun (N), *time and nature*,[3] and two as NPs. Of the latter, one (*money and property*) occurs as part of a member of the other (*the disposition of jointly held money and property*), which has five member NPs. Finally, the CS in (1)c is an adjective phrase (AP) with three member APs.

(1)

a. He is not quite *journalist or carnival barker or orator or interlocutor or master of ceremonies or trained seal*. (from the APHB corpus; see note 1)
b. Courts often need the precise *time and nature* of death to settle *manslaughter charges, inheritance claims, insurance proceeds, tax problems, and the disposition of jointly held money and property.* (from the APHB corpus)
c. I felt *exposed, unprotected, somehow afraid of what might happen*. (from the SUSANNE corpus, cited in Sampson 1995: 334)

If a CS has *n* members, then it also has from zero to *n* 1 occurrences of a 'connective', such as *and*, introducing certain of its non-initial members.[4] For example, the CS in 1a contains five occurrences of the connective *or*, each introducing a non-initial member of the CS. Each of the CSs in 1b contains one

occurrence of the connective *and* introducing the final member of that CS. Finally, the CS in 1c contains no connectives at all. CSs which contain one or more connectives, such as those in 1a and 1b, are called 'syndetic'; those which contain no connectives, such as 1c, 'asyndetic' (Quirk & Greenbaum 1973: 253).

Finally, a non-initial member together with its connective, if any, may be preceded by a noticeable juncture, or intonational break. Such junctures are sometimes indicated by a comma in written English, but sometimes not, and some occurrences of a comma do not correspond to a noticeable juncture. When representing the structure of CSs, I indicate the non-noticeable 'short' juncture by '-', and the noticeable 'long' juncture, by '+'.

2. Nesting and Embedding of Coordinate Structures

A CS which occurs as a proper part of a member of another CS, such as *money and property* in (2), may be called a 'nested CS', the CS containing it a 'nesting CS', and the phenomenon as a whole 'CS-nesting'. There is no grammatical limit to the depth of CS-nesting. In the highlighted CS in 2, *chips or strips*, which is its most deeply nested CS, is CS-nested to depth 3, so that the CS as a whole is 3CS-nesting.

(2) Enriched with minerals and vitamins, the purified soybean meal is *colored, flavored, pressed, shaped and cut into bits that look and taste like bacon* ***chips or strips****, pork sausage, ground beef, sliced ham or chicken and are cheaper and just as nourishing as the real thing*. (from the APHB corpus)

A CS can also occur as a member of another CS. I call the former an 'embedded CS', the latter an 'embedding CS', and the phenomenon as a whole 'CS-embedding'. CS-embedding is exemplified by the highlighted CS in (3), an embedding CS whose first member is the embedded CS *cluster together and groom each other*. Its structure is shown in (4), where brackets indicate CS-embedding, and '-' and '+' indicate short and long junctures.

(3) The bush babies *cluster together and groom each other, or run through the trees in gangs*. (from the APHB corpus)

(4) [cluster together - and groom each other] + or run through the trees in gangs

The 'ultimate members' of a CS are its members which are not CSs together with the ultimate members of its members which are. Accordingly, the highlighted CS in (3) has two members and three ultimate members. Its most deeply CS-embedded ultimate member is CS-embedded to depth 1, so that the CS as a whole is 1CS-embedding. A CS whose members are identical to its ultimate members, such as those in (1), is 0CS-embedding. CS-embedding occurs in such a way as to prevent the following conditions from arising.

(5)

a. Members of a CS are introduced by different connectives.
b. Members of a CS are introduced by different junctures
c. Long junctures occur in CS-embedded members of a CS containing short junctures.
d. A member of a CS which is introduced by a connective is followed by one which is not.

Without CS-embedding, the CS in 3 manifests both conditions (5)a and b: its second and third members are introduced by different connectives, and they are introduced by a different junctures. However, with CS-embedding as in (4), none of the conditions in (5) is present.

In 6, I give examples in which exactly one of each of the conditions in (5)a, b and d arises in the absence of CS-embedding. As a result they are all analyzed with 1CS-embedding as in 7.

(6)

a. Caroline was going into the possibility of *the Pope or his priests and the nuns*. (condition (5)a, from the APHB corpus)
b. *I took the whole thing and I threw it in his face, and I jumped over the counter, and there was a fork and I used that to stab him in the face.* (condition (5)b, modified from the APHB corpus by the addition of the underlined word)
c. Of course, an employer has a right to refuse to hire a man if he doesn't like *the color of his tie, or his diction, his shifty eyes, or his having taken the Fifth Amendment*. (condition (5)d, from the APHB corpus)[5]

(7)

a. i. [the Pope - or his priests] - and the nuns
   ii. the Pope - or [his priests - and the nuns]
b. [I took the whole thing - and I threw it in his face] + and I jumped over the counter + and [there was a fork - and I used that to stab him in the face]
c. i. [the color of his tie + or his diction] + his shifty eyes + or his having taken the Fifth Amendment
   ii. the color of his tie + or [his diction + his shifty eyes + or his having taken the Fifth Amendment]

Condition (5)c is needed to prevent CS-embedding structures such as that in (8) from arising.

(8) *I took the whole thing - and [I threw it in his face + and I jumped over the counter + and there was a fork] - and I used that to stab him in the face.

The highlighted CSs in (9) do not appear to manifest any of the conditions in (5); yet they may be analyzed as having the 1CS-embedding structures in (10) (junctures omitted).

(9)

a. That's our job and that's the job of *Brezhnev and Kosygin and Mao Tse-tung and Chou En-lai*. (from the APHB corpus)
b. Then Dr. White and his faculty and students could *assemble and throw rocks at each other and play with matches and burn things down*. (from the APHB corpus)

(10)

a. [Brezhnev and Kosygin] and [Mao Tse-tung and Chou En-lai]
b. [assemble and throw rocks at each other] and [play with matches and burn things down]

However, when those CSs are spoken with the intended interpretations, a long juncture appears before the connective introducing the third ultimate member. Hence without CS-embedding, these CSs would actually manifest condition (5)b. The actual structures of these CSs with those interpretations are therefore those shown in (11).

(11)

a. [Brezhnev - and Kosygin] + and [Mao Tse-tung - and Chou En-lai]
b. [assemble - and throw rocks at each other] + and [play with matches - and burn things down]

Without CS-embedding, the CSs highlighted in (12) would manifest conditions (5)a, (5)d, and possibly also (5)b simultaneously.

(12)

a. a company of persons gathered for *deliberation and legislation, worship or entertainment* (from the definition of *assembly* in Webster's Collegiate Dictionary, 7th edition)
b. The girls are brought in *frightened or defiant, cursing and fighting or sullen and withdrawn*. (from the APHB corpus)

If all of the ultimate members of the CS in (12)a are introduced by short junctures, then that CS has the 1CS-embedding analyses in (13)a (the most likely analysis on semantic grounds) and (13)b. If the comma corresponds to a long juncture, then that CS has the 1CS-embedding analysis in (13)c.

(13)

a. [deliberation - and legislation] - worship - or entertainment
b. deliberation - and [legislation - worship - or entertainment]
c. [deliberation - and legislation] + [worship - or entertainment]

Similarly, if all of the ultimate members of the CS in (12)b are introduced by short junctures, then that CS has the 1CS-embedding analyses in (14)a(the most likely analysis on semantic grounds) and (14)b. If the comma corresponds to a long juncture and all the other junctures are short, then that CS has the 2CS-embedding analysis in (14)c.[6]

(14)

a. frightened - or [defiant - cursing - and fighting] - or [sullen - and withdrawn]
b. [frightened - or defiant] - [cursing - and fighting] - or [sullen - and withdrawn]
c. [frightened - or defiant] + [[cursing - and fighting] - or [sullen - and withdrawn]]

Another CS which manifests three of the conditions in (5) without CS-embedding is highlighted in (15).

(15) Combine grapefruit with *bananas, strawberries and bananas, bananas and melon balls, raspberries or strawberries and melon balls, seedless white grapes and melon balls, or pineapple cubes and orange slices*. (from the APHB corpus)

The CS in (15) can only be analyzed as in (16), i.e. as a six-membered syndetic CS, whose fourth member (*raspberries or strawberries and melon balls*) is a CS whose first or second member must also be a CS; hence the entire CS manifests 2CS-embedding.[7]

(16)

a. bananas + [strawberries - and bananas] + [bananas - and melon balls] + [[raspberries - or strawberries] - and melon balls] + [seedless white grapes - and melon balls] + or [pineapple cubes - and orange slices]
b. bananas + [strawberries - and bananas] + [bananas - and melon balls] + [raspberries - or [strawberries - and melon balls]] + [seedless white grapes - and melon balls] + or [pineapple cubes - and orange slices]

3. Strict Upper Bound on Coordinate Structure Embedding

CS-embedding in English arises only to prevent the conditions in (5) from arising. Hence, when those conditions are absent, as in the CSs in (1), so is CS-embedding. Moreover, only as much CS-embedding occurs as is necessary to eliminate those conditions. Although there are three conditions to be avoided, at most 2CS-embedding is required to eliminate them. Assuming that CS-embedding is

used only to avoid conditions like those in (5) in all languages, and that in all languages there is only a small number of such conditions to avoid, it follows that similar limitations on CS-embedding hold for all languages. That is, there is a strict upper bound on the degree of CS-embedding in all languages, and in English that bound is 2.

The limitation on degree of CS-embedding obtains even when the structures are strictly left or right branching, and not center embedding; for example, the structure in (17) is strictly right branching, but it is impossible.

(17) *journalist + or [carnival barker + or [orator + or [interlocutor + [or master of ceremonies + or trained seal]]]]

Since multiple left and right branching do not by themselves lead to unacceptability (Chomsky 1965: 13-14), the only explanation for the unacceptability of *n*CS-embedding in English, where $n > 2$, is that it is ungrammatical.

4. Previous Treatments of Coordinate Structure Embedding

There is a tradition of analyzing CSs as having right-branching analyses of unbounded depth of CS-embedding rather than analyses with strictly limited depth of CS-embedding, going back at least to Yngve (1960), and which has been revived in recent work within the Minimalist Program (Chomsky 1995), proposing that the structure of CSs is governed by X-bar theory (e.g., Johannessen 1993, Munn 1993, Zoerner 1995).

Chomsky (1965: 196) points out the untenability of this tradition:

> [I]t is surely impossible to assume, with Yngve, that in the phrase "John, Mary, and their two children" the structure is [*John*][[*Mary*][*and their two children*]], so that "John" is coordinated with "Mary and their two children," the latter being analysed into the coordinated items "Mary" and "their two children". This is entirely counter to the sense.

Chomsky's own view is that CSs have only 0CS-embedding analyses. For example, Chomsky & Miller (1963: 298) simply rule out the possibility of CS-embedding by definition:

> Clearly, in the case of true coordination, by the very meaning of this term, no internal structure should be assigned at all within the sequence of coordinate items.

The one example Chomsky & Miller (1963) provide to illustrate 'true coordination' is the syndetic CS *old, tired, tall, ... and friendly*, which indeed has only the one analysis with "no internal structure". They simply do not consider examples such as those in (3), (6), (9), (12) and (15), which can only be analyzed as having either 1CS- or 2CS-embedding.

Chomsky (1965: 196), however, does acknowledge that CSs may have right-branching embedding structure:

> Notice ... that conjunction *can* have [an embedding] structure (e.g., "John, as well as Mary and her child"), but surely it is false to claim that it *must* have this structure.

However, it is noteworthy that in illustrating CS-embedding, Chomsky switches to the connective *as well as* rather than using the standard conjunctive connective *and*.

The view that CSs have only 0CS-embedding structures is undoubtedly rooted in traditional grammar. It was also adopted implicitly by Bloomfield (1933: 195), and explicitly by Wells (1947 [1966:198-199]), who, after observing that most constructions are analyzed into exactly two immediate constituents (ICs), asks:

> [S]hould not the sequence *men, women, and children* be analyzed into three coordinate ICs: *men,*| *women,*| *and children*?

Wells immediately answers his own question in the affirmative, based on a 'criterion of indifference' which he formulates as follows:

> Given a constitute consisting of three continuous sequences *A*, *B*, and *C*, then, if no reason can be found for analyzing it as *AB*|*C* rather than *A*|*BC*, or as *A*|*BC* rather than *AB*|*C*, it is to be analyzed into three correlative ICs, *A*|*B*|*C*. Similarly, four ICs may be recognized when no analysis into two and no analysis into three ICs is recommended, and so on.

Wells uses his criterion of indifference to draw the same conclusion for the CS *He huffed and he puffed and he blew the house down*, though his remark about the intonation contour that accompanies this analysis suggests that he was aware of the possibility of its having a 1CS-embedding analysis when a long juncture precedes the second connective as in (18).

(18) *He huffed - and he puffed + and he blew the house down*.

Several investigators such as Gleitman (1965) and Sampson (1995) have noted the possibility that CSs may have both nonembedding and embedding analyses. However, both Gleitman and Sampson consider unbounded right-branching CS-embedding structures to be well formed, and Sampson also considers unbounded left-branching CS-embedding structures to be well formed.

Gleitman contends that syndetic CSs with four ultimate members and three identical connectives such as (19) can be associated with three structures: one 0CS-embedding as in (20)a; one 1CS-embedding as in (20)b; and one 2CS-embedding, but right-branching, as in (20)c.

(19) Today we have *ham and tongue and tuna fish and pastrami.* (from Gleitman 1965)

(20)

a. ham and tongue and tuna fish and pastrami
b. [ham and tongue] and [tuna fish and pastrami]
c. ham and [tongue and [tuna fish and pastrami]]

Gleitman further contends that the structures in (20)a and c are associated with one characteristic intonation pattern, with approximately equal breaks before each connective (i.e., all short junctures or all long ones); whereas (20)b is associated with the other pattern, with short junctures before the first and third connective, and a long juncture before the second.

Gleitman admits that the claim that the same intonation pattern is associated with two radically different structures is "perhaps a misfortune", but resolves it "by the simple stratagem of making the deletion of the conjoining morpheme obligatory when two C's [connectives] are dominated immediately by the same node" (1965: 278). But this solution flies in the face of the fact that (19) is 0CS-embedding, and not 2CS-embedding, when spoken with approximately equal breaks before each connective. If there is a rule deleting repeated connectives in 0CS-embedding structures, it is optional, not obligatory.

As we have seen, the intonation pattern that Gleitman correctly associates with 0CS-embedding structures like (20)a is never associated with right-branching CS-embedding structures like (20)c. In fact, there is no way of introducing junctures into the CS in (19) which results in a 2CS-embedding structure of any sort. At most, 1CS-embedding structures can be induced by such a strategy, as shown in (21).

(21)

a. ham + and [tongue - and tuna fish - and pastrami]

b. [ham - and tongue] + and [tuna fish - and pastrami] (cf. (20)b)
c. [ham - and tongue - and tuna fish] + and pastrami
d. ham + and tongue + and [tuna fish - and pastrami]
e. ham + and [tongue - and tuna fish] + and pastrami
f. [ham - and tongue] + and tuna fish + and pastrami

Sampson (1995: 314), on the other hand, considers the potentially unbounded right-branching CS-embedding structure "as the 'unmarked' type of co-ordination, invoked when there is no clear evidence for other groupings of constituents". Such evidence includes "the common device of including a conjunction before only the last of three or more conjuncts, separating the others by comma only [, which] indicates 'flat' coordination". In effect, he proposes that a syndetic CS with *n* ultimate members and *n*-1 connectives is normally associated with a right-branching (*n*-1)CS-embedding structure, but that a syndetic CS with *n* ultimate members, but only one connective, which introduces the final member, is normally associated with a 0CS-embedding structure.

However, the one example Sampson gives to illustrate the 'unmarked type of coordination' can hardly be considered to be 'unmarked', since its second and third ultimate members are introduced by the distinctive connectives *but* and *and*.

(22) *It also appears that ää/áá increases as á increases, but this is only noticeable at the higher values of C_j, and for C_j = 4.0, á = 20 deg, ää/áá is still less than 0.4 at the extended chord-line position*. (from the SUSANNE corpus, cited in Sampson 1995: 314)

As we have seen, if an *n*-membered syndetic CS with *n*-1 occurrences of a connective is phrased with approximately equal breaks before each connective, which surely is its 'unmarked' phrasing, it must be 0CS-embedding.

5. Finite-State, Phrase-Structure, and Transformational Analyses of Coordinate Structures

Given that the upper bound on CS-embedding is part of linguistic competence rather than performance, and ignoring the internal structure of the members (hence ignoring the problem of CS-nesting), the possibility of other sources for CSs besides the coordinating of members of the same category, and other restrictions on what may be coordinated, the analysis of CSs in any natural language can be provided by a finite-state grammar, and be parsed by a finite-state transducer. To formulate such a grammar and transducer is not difficult, but the results are not elegant, involving massive numbers of states and transitions. More elegant formulations are possible if the theory of recursive transition networks (Woods 1970) or a theory based on constraint satisfaction (see below) is used instead.

Curiously, given the apparent descriptive adequacy of the theory of finite-state grammar for the analysis of the overall structure of CSs, the focus of early work in generative grammar on the analysis of CSs, especially in Chomsky (1955 [1975]), was on the *inadequacy* of the theory of phrase-structure grammar. The difficulty arises from the way in which a phrase-structure grammar assigns structure to the strings it generates. Suppose that syndetic CSs of category *A* are generated by application of rule (23), where *Co* is a connective.

(23) $A \rightarrow A\ Co\ A$

Reapplying rule (23) to its own output and holding *Co* constant results in the generation of CSs with any number *n* ultimate members and *n*-1 identical connectives. However, all those CSs and their embedded members have exactly two members, so that every CS with three or more ultimate members generated by (23) manifests CS-embedding.[8]

This problem can be overcome by the use of rule schemata as in (24) (Chomsky & Schützenberger 1963; see also Gazdar et al. 1985), where *Co* is a specific connective.

(24) $A \rightarrow A\ Co\ A\ (Co\ A)^*$, where $(Co\ A)^*$ is zero or more occurrences of *Co A*.

Schema (24) associates a 0CS-embedding structure with any CS of category *A* with *n* ultimate members and *n*-1 connectives. However, it also associates all structures with up to (*n*-2)CS-embedding to any such CS. Hence, it massively overassigns structures to the CSs it generates.[9]

Chomsky (1955 [1975: 556-559]) proposes on the basis of these and other difficulties with the phrase-structure analysis of CSs, an analysis using a family of generalized transformations. In addition to generating CSs, these transformations express the notion of 'conjunction reduction'; for example, all of the sentences in (25) are derived from the set of 'kernel' sentences in (26).[10]

(25)

a. *Alice amazed the audience and she astonished them*. (coordination of *S*)
b. Alice *amazed the audience and astonished them*. (coordination of *VP*)
c. Alice *amazed and astonished* the audience. (coordination of *V*)

(26) {Alice amazed the audience, Alice astonished the audience}

However, neither Chomsky's original transformational analysis nor any subsequent one deals with any of the issues involving CS-embedding.

6. An Optimality-Theoretic Analysis of CS-Embedding

As mentioned in Section 1, an insightful treatment of CS-embedding is possible using Optimality Theory. Suppose that CSs are evaluated on the basis of inputs consisting of sequences of already structured members, together with connectives and junctures preceding them. Let *X*, *Y*, ... be members, *c* and *d* be connectives, and '+' and '–' be junctures. Then, *X – c Y + d Z – W* exemplifies a possible input. Output candidates are all the CSs that may be associated with a particular input, including those that rearrange the formatives, delete some, and introduce others. The optimal (winning) candidates are those that best satisfy the constraint hierarchy for CSs. One of the constraints in the hierarchy is the NOCSE constraint stated in (27).

(27) NOCSE: A CS may not be a member of a CS.

For example, given the input *men – women – and children*, NOCSE selects the analysis of it as a three-membered syndetic CS, just as Wells (1947 [1966]) concluded.

(28) Tableau for the CS *men – women – and children*

men – women – and children	NOCSE
☞ men – women – and children	
[men– women] – and children	*!
men – [women – and children]	*!

Similarly, for the CS in (1)a, NOCSE selects as the optimal output the 0CS-embedding structure out of the 197 candidates (see note 9) which are faithful to the input sequence but which are consistent with any possible CS-embedding.[11]

(29) Tableau for the CS in (1)a

journalist + or carnival barker + or orator + or interlocutor + or master of ceremonies + or trained seal		NOCSE
☞	journalist + or carnival barker + or orator + or interlocutor + or master of ceremonies + or trained seal	
	[journalist + or carnival barker] + or orator + or interlocutor + or master of ceremonies + or trained seal	*!
	[journalist + or carnival barker] + or [orator + or interlocutor] + or master of ceremonies + or trained seal	*!
	...	...
	journalist + or [carnival barker + or [orator + or [interlocutor + [or master of ceremonies + or trained seal]]]]	*!***

Next, corresponding to each of the conditions in (5) which give rise to CS-embedding are the constraints in (30) through (33). Each of these constraints outranks NOCSE, as the tableaux in through illustrate.

(30) SAMECON: In a CS, all the connectives are the same.

(31) SAMEJCT: In a CS, all the junctures are the same.

(32) SHINLG: A member containing long junctures cannot be CS-embedded within a CS containing short junctures.

(33) *CONOCO: In a CS, a member which is preceded by a connective cannot be followed by a member which is not preceded by a connective.

(34) Tableau for (7)a

the Pope – or his priests – and the nuns		SAMECON	NOCSE
	the Pope – or his priests – and the nuns	*!	
☞	[the Pope – or his priests] – and the nuns		*
☞	the Pope – or [his priests – and the nuns]		*

(35) Tableau for (7)b

I took the whole thing – and I threw it in his face + and I jumped over the counter + and there was a fork – and I used that to stab him in the face		SH IN LG	SAME JCT	NO CSE
	I took ... – and I threw it ... + and I jumped ... + and there was a fork – and I used that ...		*!*	
	[I took ... – and I threw ...] + and I jumped ... + and there was a fork – and I used that ...		*!	*
	I took ... – and I threw ... + and I jumped ... + and [there was a fork – and I used that ...]		*!	*
☞	[I took ... – and I threw ...] + and I jumped ... + and [there was a fork – and I used that ...]			*
	I took ... – and [I threw ... + and I jumped ... + and there was a fork] – and I used that ...	*!		*
	[I took... – and I threw ... + and I jumped ...] + and [there was a fork – and I used that ...]	*!	*	*

(36) Tableau for (7)c

the color of his tie – or his diction – his shifty eyes – or his having taken the Fifth Amendment		*CONOCO	NOCSE
	the color of his tie – or his diction – his shifty eyes – or his having taken the Fifth Amendment	*!	
☞	[the color of his tie – or his diction] – his shifty eyes – or his having taken the Fifth Amendment		*
☞	the color of his tie – or [his diction – his shifty eyes – or his having taken the Fifth Amendment]		*

Next, note that the effect of different junctures when used together with different connectives, as in the highlighted CS in (3), is to make clear the scope of each connective.

(37) Tableau for (4)

cluster together – and groom each other + or run through the trees in gangs		SAME CON	SHIN LG	NO CSE
	cluster together – and groom each other + or run through the trees in gangs	*!	*	
☞	[cluster together – and groom each other] + or run through the trees in gangs			*
	cluster together – and [groom each other + or run through the trees in gangs]		*!	*

Next consider the analysis of the CS in (12)a in which the comma corresponds to either a short or a long junction. Let us consider first the case in which it corresponds to a short junction, not distinct from any of the others, so that the SAMEJCT and SHINLG constraints do not come into play. For this case, the SAMECON and *CONOCO constraints do not distinguish the desired winning candidates (13)a and

b from (13)c. That candidate can be ruled out by the *NOCON constraint in (38), which is ranked below SAMECON, SAMEJCT, *LGINSH, and *CONOCO, but which is not ranked with respect to NOCSE. The tableau appears in (39). On the other hand, if a distinctively long junction occurs in the position of the comma, then is correctly selected as the output, as shown in .

(38) *NOCON: A CS must contain at least one connective.

Since asyndetic CSs such as are grammatical, *NOCON must rank above any constraint that would have the effect of inserting a connective into a CS which does not appear in the input. Together with the *CONOCO constraint, *NOCON ensures that if a CS has exactly one connective, it introduces the final member.

(39) Tableau for (13)a and b

deliberation – and legislation – worship – or entertainment		SAME CON	*CO NOCO	NO CSE	*NO CON
	deliberation – and legislation – worship – or entertainment	*!	*		
☞	[deliberation – and legislation] – worship – or entertainment			*	
☞	deliberation – and [legislation – worship – or entertainment]			*	
	[deliberation – and legislation] – [worship – or entertainment]			*	*!
	[deliberation – and legislation – worship] – or entertainment		*!		
	deliberation – and [legislation – worship] – or entertainment	*!			*

(40) Tableau for (13)c

deliberation – and legislation + worship – or entertainment		SAME CON	SAME JCT	SHIN LG	*CO NOCO	*NO CON
	deliberation – and legislation + worship – or entertainment	*!	*	*	*	
	[deliberation – and legislation] + worship – or entertainment		*!			
	deliberation – and [legislation + worship – or entertainment]		*!			
☞	[deliberation – and legislation] + [worship – or entertainment]					*
	[deliberation – and legislation + worship] – or entertainment		*!	*	*	
	deliberation – and [legislation + worship] – or entertainment			*!		*

In (12)b, the comma also corresponds to either a short or long junction. If it is short, then the structures in (14)a and b are optimal; if it is long, then the structure in (14)c is.

(41) Tableau for (14)a and b

frightened – or defiant – cursing – and fighting – or sullen – and withdrawn	SAME CON	*CO NOCO	NO CSE	*NO CON
frightened – or defiant – cursing – and fighting – or sullen – and withdrawn	*!*	*		
☞ frightened – or [defiant – cursing – and fighting] – or [sullen – and withdrawn]			*	
☞ [frightened – or defiant] – [cursing – and fighting] – or [sullen – and withdrawn]			*	
[frightened – or defiant] – [cursing – and fighting – or sullen – and withdrawn]	*!		*	*
[frightened – or defiant] – [[cursing – and fighting] – or [sullen – and withdrawn]]			**!	*
frightened – or [defiant – cursing – and [fighting – or [sullen – and withdrawn]]]			**!*	

(42) Tableau for (14)c (omitting some candidates)

frightened – or defiant + cursing – and fighting – or sullen – and withdrawn	SAME CON	SAME JCT	*CO NOCO	NO CSE	*NO CON
frightened – or [defiant + cursing – and fighting] – or [sullen – and withdrawn]		*!		*	
[frightened – or defiant] + [cursing – and fighting] – or [sullen – and withdrawn]		*!		*	
☞ [frightened – or defiant] + [[cursing – and fighting] – or [sullen – and withdrawn]]				**	*

Finally consider the CS in (15), whose optimal outputs are 2CS-embedding.

(43) Tableau for (15) (many candidates omitted)

	bananas + strawberries – and bananas + bananas – and melon balls + raspberries – or strawberries – and melon balls + seedless white grapes – and melon balls + or pineapple cubes – and orange slices	SAME CON	SAME JCT	*CO NO CO	NO CSE	*NO CON
	bananas + strawberries – and bananas + bananas – and melon balls + raspberries – or strawberries – and melon balls + seedless white grapes – and melon balls + or pineapple cubes – and orange slices	*!*	*****	***		
	bananas + [strawberries – and bananas] + [bananas – and melon balls] + [raspberries – or strawberries – and melon balls] + [seedless white grapes – and melon balls] + or [pineapple cubes – and orange slices]	*!			*	
☞	bananas + [strawberries – and bananas] + [bananas – and melon balls] + [[raspberries – or strawberries] – and melon balls] + [seedless white grapes – and melon balls] + or [pineapple cubes – and orange slices]				**	
☞	bananas + [strawberries – and bananas] + [bananas – and melon balls] + [raspberries – or [strawberries – and melon balls]] + [seedless white grapes – and melon balls] + or [pineapple cubes – and orange slices]				**	

The preceding analysis indicates that for CSs in English that contain at most two distinct connectives and junctures, the maximum depth of CS-embedding that is required to eliminate SAMECON, SAMEJCT, SHINLG, and *CONOCO violations in English is 2.[12] This limitation on CS-embedding is most effectively accounted for by a system of ranked constraints applied to candidates constructed without limitation, as in the Optimality Theoretic account proposed here. It does not require imposing an arbitrary numerical bound on an otherwise unrestricted recursive mechanism, but follows simply as a consequence of constraint interaction.

7. Long Junctures and Breathing, Coordination and Subordination

The appearance of long junctures in CSs relates not only to CS-embedding but also to breathing. For example, the CS in (1)a, which has six ultimate members and five identical connectives, is most naturally spoken with a long juncture preceding each connective, as indicated in the tableau in (29). It can also be spoken with a short juncture preceding each connective, but the result would sound rushed, as if the speaker might run out of breath before finishing it. However, one does not need to insert a long juncture before every connective in order to provide sufficient opportunities to inhale; one or two long junctures would suffice. But if one inserts a single long juncture before, say, the third connective; or two long junctures, one before the second and one before the fourth connective, the result would be 1CS-embedding, so as to avoid SAMEJCT and SHINLG violations. Thus one accommodates one's need both to breathe and to convey 0CS-embedding when uttering a lengthy CS by pausing before each member.

In addition to regulating CS-embedding, junctures also distinguish to some extent between CSs and subordinate structures (SSs), as in (44) (junctures omitted).

(44) I know *that you don't believe that you're an atheist*.

If a short juncture appears before the second *that*, (44) is unambiguous. It has only the 2SS-embedding structure (45).

(45) I know [that you don't believe – [that you're an atheist]]

However, if a long juncture appears in that position, (44) is ambiguous. It has either the structure (45) (with '+' in place of '–'), or the 1SS- and 0CS-embedding structure (46).[13]

(46) I know [[that you don't believe] + [that you're an atheist]]

That is, in a series of clauses, a non-initial clause introduced by a short juncture is understood only as a subordinate clause, whereas one introduced by a long juncture may be understood either as a subordinate clause or as a member of a CS. This restriction on non-initial clausal members of a CS is expressed by the LGMBR constraint.

(47) LGMBR: A non-initial clausal member of a CS which is not introduced by a connective must be introduced by a long juncture.

This constraint is ranked even above the faithfulness constraints for junctures, so that the output corresponding to an input in which a short juncture appears before a non-initial clausal member of a CS contains a long juncture in that position.

I account for the fact that subordinate clauses can be introduced by either short or long junctures by assuming that there are no constraints which alter whatever input juncture that appears in that position. Thus a long juncture can appear before each *that* in and that sentence can still be understood as 2SS-embedding.

The appearance of long junctures in right- and left-branching SSs has been interpreted to indicate that they are 'unnatural' in some way (Chomsky 1965: 13):

> [T]here are no clear examples of unacceptability involving only left-branching or only right-branching, although these constructions are unnatural in other ways ... thus, for example, in reading the right-branching construction "this is the cat that caught the rat that stole the cheese," the intonation breaks are ordinarily inserted in the wrong places (that is, after "cat" and "rat," instead of where the main brackets appear)[.]

However, the intonation breaks in Chomsky's example and in (44) (with a break before each occurrence of *that*) are not in the 'wrong places'. Long junctures routinely introduce clauses in English regardless of their function. They may, but do not have to be, interpreted as indicating that those clauses are coordinate rather than subordinate.

Examples like those Chomsky cites involving relative clauses lend additional support for the LGMBR constraint. Compare his example, repeated in (48)a, with an otherwise identical example in which the first relative clause is replaced by one which does not contain a noun phrase that can be modified by the second relative clause. In addition, consider the possibility of long and short juncture before the second relative clause in both examples.

(48)

a. This is the cat *that chased the rat that stole the cheese*.
b. This is the cat *that lives next door that stole the cheese*.

With long juncture in that position, (48)a is ambiguous, having both the 2SS-embedding structure in (49)a, and the 1SS- and 0CS-embedding structure in (49)b.[14]

(49)

a. This is the cat [that chased the rat + [that stole the cheese]]
b. This is the cat [[that chased the rat] + [that stole the cheese]]

With short juncture in that position, (48)a is unambiguous, having only the 2SS-embedding structure in (49)a (with '–' replacing '+'), as a consequence of a LGMBR violation in the counterpart to (49)b.

On the other hand, with long juncture in that position, (48)b is unambiguous, having only the 1SS- and 0CS-embedding structure in (50); and with short juncture in that position, it is ungrammatical: LGMBR does not permit the second relative clause to be understood as coordinate to the first, which is the only way that it can be understood.

(50) This is the cat [[that lives next door] + [that stole the cheese]]

In sequences of clauses, then, short junctures unambiguously indicate subordination, but long junctures do not distinguish between subordination and coordination. However, in sequences of locative prepositional phrases (PPs), as in (51), not only do short junctures unambiguously indicate subordination, but long junctures also unambiguously indicate coordination.

(51) The circle is above the diamond beside the square.

If a short junction precedes the preposition *beside* in (51), the PP *beside the square* modifies, and consequently is subordinate to, the NP *the diamond* within the PP *above the diamond*, as in (52)a. On the other hand, if a long junction precedes *beside*, the PP *beside the square* is coordinate with the PP *above the diamond*, as in (52)b.

(52)

a. [above the diamond – [beside the square]]
b. [[above the diamond + [beside the square]]

These judgments can be accounted for by the LGMBR constraint, generalized to apply to PP as well as clausal members of CSs, and a constraint that requires subordinate PPs to be introduced by a short juncture.

(53) SHSUBPP: A subordinate PP must be introduced by a short juncture.

In written English, the junctures which introduce locative PPs are not normally distinguished. As a result, the orthographic string *above the diamond beside the square* is associated with the two distinct structures in (52), but in spoken English, in which the junctures are distinguished, the corresponding phrases are structurally unambiguous.

A series of three PPs in written English, as in (54), is associated with five distinct structures, as in (55).

(54) The circle is next to the triangle above the diamond beside the square.

(55)

a. [next to the triangle – [above the diamond – [beside the square]]]
b. [[next to the triangle] + [above the diamond] + [beside the square]]
c. [[next to the triangle] + [above the diamond – [beside the square]]]
d. [[next to the triangle – [above the diamond]] + [beside the square]]
e. [next to the triangle – [[above the diamond] + [beside the square]]]

In spoken English, there are four ways to phrase the highlighted PP sequence in (54), all but one of which are unambiguous. If a short juncture introduces the second PP and a long juncture the third, then

the third PP may be coordinated either with the 1SS-embedding phrase made up of the first two PPs ('high attachment', as in (55)d), or just with the second PP ('low attachment', as in (55)e).

The number of structures that may be associated with a sequence of *n* locative PPs in written English is the *n*+1st number in the Catalan series (see note 8), so for example, a sequence of four locative PPs is associated with 14 different structures. On the other hand, each such sequence can in principle be phrased in 2^{n-1} different ways in spoken English, so that the number of structures associated with each phrasing is much smaller.[15]

The caveat 'in principle' is necessary, because not every phrasing of long sequences of locative PPs is physically possible, assuming that speakers must eventually insert a long juncture before a preposition in order to inhale. This physical limitation imposes an indeterminate upper bound on the depth of SS-embedding of successively occurring PPs. This bound cannot be fixed, unlike in the case of CS-embedding, since the number of PPs that can be uttered in one breath depends on their length and on the lung capacity of the speaker.[16]

References

Archangeli, Diana, and D. Terence Langendoen, eds. (to appear) *Optimality Theory: An Overview*. Oxford: Blackwell.

Bayer, Samuel. (1996) The Coordination of Unlike Categories. *Language* 72: 579-616.

Bloomfield, Leonard. (1933) *Language*. New York: Henry Holt.

Chomsky, Noam. (1955) The Logical Structure of Linguistic Theory. Unpublished ms. Published as *The Logical Structure of Linguistic Theory*. New York: Plenum, 1975.

Chomsky, Noam. (1965) *Aspects of the Theory of Syntax*. Cambridge, MA: MIT Press.

Chomsky, Noam. (1995) *The Minimalist Program*. Cambridge, MA: MIT Press.

Chomsky, Noam, and George A. Miller. (1963) Introduction to the Formal Analysis of Natural Languages. In *Handbook of Mathematical Psychology, Vol. II*, ed. by R. Duncan Luce, Robert R. Bush, and Eugene Galanter, 269-321. New York: John Wiley and Sons.

Chomsky, Noam, and Marcel P. Schützenberger. (1963) The Algebraic Theory of Context-Free Languages. In *Computer Programming and Formal Systems*, ed. by Paul Braffort and D. Hirschberg, 119-161. Amsterdam: North-Holland.

Church, Kenneth, and Ramesh Patil. (1982). How to Put the Blocks in the Box on the Table. *American Journal of Computational Linguistics* 8: 139-149.

Gazdar, Gerald, Ewan Klein, Geoffrey Pullum, and Ivan Sag. (1985) *Generalized Phrase-Structure Grammar*. Cambridge, MA: Harvard University Press.

Gleitman, Lila R. (1965) The Grammar of Coordinate Compounding. *Language* 41: 260-293.

Johannessen, Janda Bondi. (1993) Coordination: A Minimalist Approach. Doctoral dissertation, University of Oslo, Norway.

Lakoff, George, and Stanley Peters. (1969) Phrasal Conjunction and Symmetric Predicates. In *Modern Studies in English*, ed. by David Reibel and Sanford Schane, 113-142. Englewood Cliffs, NJ: Prentice-Hall.

Langendoen, D. Terence, Dana McDaniel, and Yedidyah Langsam. (1988) Preposition-Phrase Attachment in Noun Phrases. *Journal of Psycholinguistic Research* 18: 533-548.

McCarthy, John, and Alan Prince. (1994) The Emergence of the Unmarked: Optimality in Prosodic Morphology. *Proceedings of NELS* 24: 333-379.

Min, Young-Gie. (to appear) Disambiguation of Coordinate Compound Expressions. Ph.D. dissertation, University of Arizona, Tucson.

Munn, Alan. (1993) Topics in the Syntax and Semantics of Coordinate Structures. Ph.D. dissertation, University of Maryland, College Park.

Nunberg, Geoffrey. (1990) *The Grammar of Punctuation*. Stanford, CA: Center for the Study of Language and Information.

Prince, Alan, and Paul Smolensky. (1993) Optimality Theory: Constraint Interaction in Generative Grammar. *RuCCS Technical Report* 2. Rutgers University Center for Cognitive Science, Piscataway, NJ.

Quirk, Randolph, and Sidney Greenberg. (1973) *A Concise Grammar of Contemporary English*. New York: Harcourt, Brace, Jovanovich.

Sampson, Geoffrey. (1995) *English for the Computer: The SUSANNE Corpus and Analytic Scheme*. Oxford: Clarendon Press.

Wells, Rulon S. (1947) Immediate Constituents. *Language* 23: 81-117. Reprinted in Martin Joos, ed., *Readings in Linguistics I: The Development of Descriptive Linguistics in America 1925-56*, 4th edition, 186-207. Chicago: University of Chicago Press, 1966.

Woods, William A. (1970) Transition Network Grammars for Natural Language Analysis. *Communications of the Association for Computing Machinery* 13: 591-606.

Yngve, Victor. (1960) A Model and an Hypothesis for Language Structure. *Proceedings of the American Philosophical Society* 104: 444-466.

Zoerner, C. Edward. (1995) Coordination: The Syntax of &P. Doctoral dissertation, University of California, Irvine.

Notes

* Prepublication version of paper that appeared in *Journal of Psycholinguistic Research* 27 (2): 235-259, 1998.

1. The initial research underlying this work was conducted in 1987, when I was a Visiting Scientist at IBM Research Center, Hawthorne, New York. I thank my hosts George Heidorn and Karen Jensen for helpful discussion of this work, both then, and in 1993, when I read an earlier version of this paper at the University of Washington, Seattle. I also thank Slava Katz for his help in identifying relevant examples in the machine-readable American Publishing House for the Blind (APHB) corpus to which I had access at IBM, and Arnold Koslow, my former colleague at the City University of New York, for his insights into the workings of the 'logical operators', of which the English words *and* and *or* are but two examples. Finally, I thank my colleagues and students at The University of Arizona, particularly Diana Archangeli, Richard Oehrle, Young-Gie Min, and Joël Magloire for their insights and encouragement.

2. Members may, under certain circumstances, belong to different grammatical categories, and arguably do not even have to be constituents. These matters have been widely discussed in the literature; see Bayer (1996) for recent discussion.

3. This CS is not an NP, since it occurs as the head of the NP *the time and nature of death.*

4. I say 'introducing' rather than 'preceded by' to leave open the possibility that the connective is part of the member it precedes. It is now generally assumed that it is, but the issue is not crucial to our discussion, and I ignore it here.

5. I interpret the fact that there is a comma before each non-initial member to mean that long junctures were intended; however, the same result is obtained if short junctures are used.

6. If there also is a long junction before the first *and*, the following 2CS-embedding analysis is possible: [frightened - or defiant] + cursing + and [fighting - or [sullen - and withdrawn]].

7. See Min (to appear) for discussion of the natural disambiguation of phrases like *raspberries or strawberries and melon balls*.

8. Church & Patil (1982) show that the number of structures $C(n)$ associated with a CS with n ultimate members generated by (23) is given by the 'Catalan numbers' defined by the recurrence relation:

$$C(1) = C(2) = 1; C(n) = \sum_{i=1}^{n-1} C(i)\, C(n-i), n > 2$$

The values of $C(3)$ through $C(12)$ are: 2; 5; 14; 42; 132; 429; 1,430; 4,862; 16,796; 58,786.

9. Andrew Neff (personal communication) has shown that the number of structures $N(n)$ associated with a CS with n ultimate members generated by (24) is given by the recurrence relation:

$$N(1) = N(2) = 1; N(n) = N(n-1) + 2\sum_{i=2}^{n-1} N(i)\, N(n-i), n > 2$$

The values of $N(3)$ through $N(12)$ are: 3; 11; 45; 197; 903; 4,279; 20,793; 103,049; 518,859; 2,646,723.

10. Chomsky's account assumes that all CSs of whatever category can be derived from sets of sentences in which the members occur singly. This assumption was first challenged by Lakoff and Peters (1969) for coordinate NPs which occur as subjects of 'symmetric predicates' such as *similar*, as in *Alice and Betty are similar*, and is no longer widely held. His analysis also does not make clear how CSs with three or more members are to be derived. Gleitman (1965) addresses this issue by proposing (on the basis of a suggestion from Chomsky) that the family of transformations can take any number of sentences as input.

11. I regard any number of 1CS-embedding members as counting as a single NOCSE violation; any number of 2CS-embedding members as a double NOCSE violation, etc.

12. The restrictions on number of distinct connectives and junctures allowed in CSs affects our conclusion in the following way. If the number of distinct connectives or junctures is increased, then the maximum depth of CS-embedding needed to eliminate all relevant violations may increase. However, there are no other distinct junctures in English (the orthographic conventions involving the contrastive use of the comma and semicolon to indicate degrees of separation are artificial and do not correspond to any phonological distinction), and there are very few other connectives in English besides *and* and *or* that need to be considered in a full account of CS-embedding, primarily *nor* and *but*. Both of these have special properties that may limit their effect on increasing the need for CS-embedding, but even if they are considered fully comparable to *and* and *or*, the maximum depth of CS-embedding needed to accommodate them increases by at most a very small amount.

13. In written English, if the structure in (46) is intended, a comma would normally be inserted before the second *that* in (44).

14. The latter structure supports an unlikely interpretation, given our stereotypes of cats and rats, but it is certainly possible; otherwise we should expect to find the sentence *this is the cat that chased the rat that purred the entire time* strange (given that cats, but not rats, purr) with long juncture before the second relative clause.

15. Church & Patil (1982) and Langendoen, McDaniel & Langsam (1988) obtain similar results about the degree of structural ambiguity of PP sequences in written English, but base them on phrase-structure analyses which are quite different from the Optimality-Theoretic analysis proposed here. I have nothing to say here about how orthographic or spoken sequences of PPs are disambiguated, except to note that the latter problem is much more circumscribed and therefore much more tractable.

16. The bound can, however, be circumvented by inhaling elsewhere in the phrase in such a way that the resulting long juncture is simply disregarded, as in: [next to the circle - [above the hexagon - [beside the oval - [next to the + triangle - [above the diamond - [beside the square]]]]]].