On the Phrasing of Coordinate Compound Structures[1]

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1. Amphibology Resulting from Binary Coordinate Compounding

Coordinate compounding provides a notoriously rich set of possibilities for amphibology (structural ambiguity), as the following example illustrates.

(1) Bill and Ilse or Chuck

Example (1) is felt to have the interpretations of the unambiguous examples (2)-(3).

(2) either Bill and Ilse or Chuck

(3) Bill and either Ilse or Chuck

The difference between these two interpretations cannot be attributed to differences in meanings in any of the words in (1); hence it must, according to widely accepted views, be attributed to a difference in structure, and more particularly to a difference in phrase structure. Figure 1 presents the rules of a simple phrase-structure grammar that generates (1) and that associates with it distinct structural descriptions that correspond to the readings in (2) and (3).

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(a) NP   --> NP CNP

(b) CNP  --> CRD NP

(c) NP   --> NOUN

(d) NOUN --> <Bill | Chuck | Ilse | ...>

(e) CRD  --> <and | or>
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Figure 1. Rules of a simple phrase-structure grammar for coordinate compounding of NPs in English.

[1] Earlier versions of this paper were presented at New York University, October 14, 1986; the 1986 NYSCOL meeting at SUNY/Albany, October 26, 1986; and at CUNY Graduate Center, December 19, 1986.

The structural descriptions that the grammar in Figure 1 associates with the string in (1) are diagrammed in Figure 2 and Figure 3.

```
Bill and Ilse or Chuck
 |    |    |   |    |
NOUN CRD NOUN CRD NOUN
 |    |    |   |    |
 NP   |    NP  |    NP
 |    |____|   |____|
 |     CNP      CNP
 |______|        |
   NP            |
    |____________|
         NP
```

Figure 2. The structural description of (1) with respect to the grammar in Figure 1 that corresponds to the reading (2).

```
Bill and Ilse or Chuck
 |    |    |   |    |
NOUN CRD NOUN CRD NOUN
 |    |    |   |    |
 NP   |    NP  |    NP
 |    |    |   |____|
 |    |    |    CNP
 |    |    |_____|
 |    |      NP
 |    |_____|
 |     CNP
 |______|
   NP
```

Figure 3. The structural description of (1) with respect to the grammar in Figure 1 that corresponds to the reading (3).

The number of structures associated by the grammar in Figure 1 with phrases consisting of _n_ conjoins grows exponentially with _n_.[2] Figure 4 presents the number of structures associated with phrases with up to 10

[2] We follow Quirk and Greenbaum (1973) in using the term 'conjoin' to refer to the phrases that are ultimately connected by a coordinating particle. We reserve the term 'conjunct' to refer to conjoins connected by _and_ and 'disjunct' to refer to conjoins connected by _or_.

conjoins. The progression in Figure 4 consists of the Catalan numbers which can be computed by means of the formula in (4).[3]

(4) $C(n) = (2n-2)!/n!(n-1)!$

It is easily determined that the ratio of two adjacent Catalan numbers approaches 4 in the limit; that is, the progression grows by slightly less than the power of 4. This result is typical of the 'combinatorial explosion' in degree of amphibology predicted by simple phrase-structure grammars.

Number of conjoins	Number of structures
2	1
3	2
4	5
5	14
6	42
7	132
8	429
9	1430
10	4862

Figure 4. Number of structures associated with coordinate compound phrases generated by the grammar in Figure 1 as a function of the number of conjoins.

2. Amphibology Resulting from Unbounded Coordinate Compounding

The coordinate compound structures that the grammar in Figure 1 generate all have exactly two conjoins per constituent. However, coordinate compound structures in natural languages may have any number of conjoins per constituent greater than one. For example, the string in (5) may be understood as having the 'flat' structure shown in Figure 5, as well as nested structures that correspond to those in Figure 2 and Figure 3 with the word *and* substituted for the word *or*.

(5) Bill and Ilse and Chuck

The interpretation of (5) corresponding to the structure in Figure 5 is that of a group of three individuals; the other interpretations are those of a group made up of an individual and a subgroup of two individuals, with varying identification of the individual and the members of the subgroup.

[3] I thank Slava Katz for the formula in (4). The corresponding formula in Church and Patil (1982: 141) actually computes the values of $C(n+1)$. They also give an incorrect value for $C(8)$.


```
Bill and Ilse and Chuck
 |    |    |    |    |
NOUN CRD NOUN CRD  NOUN
 |    |    |    |    |
 NP   |    NP   |    NP
 |    |____|    |____|
 |     CNP       CNP
 |______|_________|
        NP
```

Figure 5. A structural description of (5) without internal conjuncts.

We obtain a grammar that is able to associate flat structures as well as nested ones with coordinate compound constructions by replacing rule (a) in the grammar in Figure 1 with the schema in (a').

(a') NP ---> NP (CNP)* CNP

However, the degree of amphibology predicted by this new grammar is much greater than that predicted by the grammar in Figure 1, as shown in the table in Figure 6 we refer to these numbers as 'generalized Catalan' numbers.[4]

Number of conjoins	Number of structures
2	1
3	3
4	11
5	45
6	197
7	903
8	4279
9	20793
10	103049

Figure 6. Number of structures associated with coordinate compound phrases generated by the grammar in Figure 1, with rule schema (a') replacing rule (a), as a function of the number of conjoins.

The values in Figure 6 may be calculated by the following tedious, but straightforward, method. Let S(*n*) be the number of structures asso-

[4] I thank Andy Neff for his help in determining these values.

ciated with a string generated by the grammar in question with n conjoins, and let S(1) = 1. Suppose we know the values of S(n) for all n up to some number k We determine S(k+1) as follows. First, let m(i), 1 <= i <= k, be the number of daughters of the root node that dominate exactly i conjoins. Then we have the equality in (6), since the number of conjoins of all the daughters of the root node must be exactly k+1.

$$(6)\quad \sum_{i=1}^{k} i*m(i) = k+1$$

To illustrate the general problem of how to calculate S(k+1), consider how we would determine the value of S(4), based on the values of S(1), S(2) and S(3). In Figure 7, are listed all the combinations of values of m(i) that satisfy (6).

Case	m(1)	m(2)	m(3)
1	4	0	0
2	2	1	0
3	1	0	1
4	0	2	0

Figure 7. Combinations of m(i) for k=3 satisfying the equality in (6).

In particular, consider case (3) in Figure 7. How many structural descriptions correspond to that case? The root node has two daughters; one contains one conjoin, the other contains three. These may be arranged in two different ways. The daughter with one conjoin may have S(1)=1 different structural arrangements. The daughter with three conjoins may have S(3)=3 structural arrangements. Therefore, the total number of structural descriptions associated with this case is 2*1*3=6. The numbers of structural descriptions corresponding to the other cases are computed in a similar way.

The general formula for computing S(k+1) is given in (7).[5]

$$(7)\quad S(k+1) = \sum \binom{m(1)+\ldots+m(k)}{m(1)\ \ldots\ m(k)} \prod_{i=1}^{k} S(i)**m(i),$$

for all k-tuples <m(1),...,m(k)>, that satisfy (6).

[5] Janda (1975) describes a program for calculating S, but it gives incorrect results for values of k greater than 7.

3. Flat Structure and Mixed Coordinators

In section 2, we illustrated flat coordinate compound structures with examples that all contained exactly the same coordinators, but the grammar that we developed in that section permits phrases with mixed coordinators, such as (1), to have flat structures as well. That is, that grammar assigns three distinct structural descriptions to (1), not two. However, it does not appear that the flat structure of (1) can be directly assigned a meaningful interpretation. Its status is rather like that of unparenthesized arithmetic expressions with nonassociative operators, such as (8), that are permitted by the syntax of programming languages.

(8) 2 + 3 * 6

Such expressions cannot be evaluated as such, since they do not tell us which operation (addition or multiplication) to apply first. Only expressions with operands grouped by parentheses can be interpreted, such as (9) and (10).

(9) (2 + 3) * 6

(10) 2 + (3 * 6)

The fact that (8) has no interpretation as it stands, however, does not mean that it cannot be assigned an interpretation by convention. For example, it may be decided to group the operands in expressions like (8) pairwise from left to right, thus giving (8) the interpretation of (9). Or it may be decided that multiplication should have 'priority' over addition, thus giving (8) the interpretation of (10). Whatever is decided about the interpretation of (8), all three expressions (8)-(10) are syntactically well-formed in the programming languages in which they occur, and none of them is ambiguous.

Returning to natural-language examples like (1), we see that we have no uniform convention for interpreting flat structures with mixed coordinators in natural languages. In the case of (1), we may interpret it either as (2) or (3), or give it no interpretation at all. In other cases, we may be guided by our experience to favor one or another interpretation. For example, when confronted with a restaurant menu that offers us the choices in (11) and (12), we most likely would interpret (11) as (13) and (12) as (14), respectively, on the grounds that soup and crackers are generally served together and that tea or coffee is generally offered as a choice together with dessert.

(11) soup and crackers or juice

(12) dessert and tea or coffee

(13) either soup and crackers or juice

(14) dessert and either tea or coffee

In an interesting set of experiments, Streeter (1978) showed how arithmetic expressions like (8) can be reliably disambiguated in speech by means of durational and intonational cues. English expressions like (1) can be similarly disambiguated. Using a broken vertical bar to indicate a phrasing cue (prolongation of the immediately preceding phrase and/or an intonational break), (1) can be phrased in the three ways indicated in (16)-(18).

(16) Bill and Ilse ¦ or Chuck

(17) Bill ¦ and Ilse or Chuck

(18) Bill ¦ and Ilse ¦ or Chuck

The phrasing in (16) has the interpretation of (2); (17) has the interpretation of (3); and (18) has the interpretation of the flat structure. (Note that (18) has the same interpretation as (1) said without any internal phonological phrasing.) If English intonation could be reliably encoded in writing, then (1) would no longer be an amphibology; each of the spoken versions (16)-(18) would have its own exact written counterpart.

4. <u>On the Distinctions Rendered by English Phrasing</u>

However, English phrasing is not adequate to distinguish among all the possible structures that the phrase-structure schema in section 2 assigns to coordinate compound expressions with four or more conjoins. Consider the following example, with four conjoins.

(19) Bill and Chuck or Ilse or Terry

Example (19) may be said without internal phrasing (in which case, like (1), it is interpreted as having flat structure), or it may be said with any of the internal phrasings in (20)-(26).

(20) Bill ¦ and Chuck or Ilse or Terry

(21) Bill and Chuck ¦ or Ilse or Terry

(22) Bill and Chuck or Ilse ¦ or Terry

(23) Bill ¦ and Chuck ¦ or Ilse or Terry

(24) Bill ¦ and Chuck or Ilse ¦ or Terry

(25) Bill and Chuck ¦ or Ilse ¦ or Terry

(26) Bill ¦ and Chuck ¦ or Ilse ¦ or Terry

These phrasings have interpretations that correspond to the bracketings in (27)-(33).

(27) (Bill) and (Chuck or Ilse or Terry)

(28) (Bill and Chuck) or (Ilse or Terry)

(29) (Bill and Chuck or Ilse) or (Terry)

(30) (Bill) and (Chuck) or (Ilse or Terry)

(31) (Bill) and (Chuck or Ilse) or (Terry)

(32) (Bill and Chuck) or (Ilse) or (Terry)

(33) (Bill) and (Chuck) or (Ilse) or (Terry)

The crucial observation is that intonational cues are not used to indicate more than one level of embedding; their only function is to chunk the total expression into subphrases at the first level of embedding. Accordingly, in a phrase of <u>n</u> conjoins, intonational cues can be used to distinguish at most 2**(n-1)-1 different structures, far fewer than the number of structures that are theoretically possible given the grammar in section 2. To indicate subordination of conjoins, one must resort to paraphrase. For example, the logical structure in (34) may be expressed as in (35).

(34) (Bill and (Chuck or Ilse)) or (Terry)

(35) either Bill and either Chuck or Ilse or Terry

However, while the use of <u>either</u> to mark the beginning of a disjunction with a correlative occurrence of <u>or</u> is unrestricted in English, the corresponding use of <u>both</u> with correlative <u>and</u> is limited to phrases with exactly two conjoins. Hence there is no easy way to produce many of the logical structures predicted by the grammar in section 2 in English. Moreover, phrases with nested occurrences of <u>either</u>...<u>or</u> and <u>both</u>...<u>and</u> quickly become difficult to understand because of center embedding.

5. <u>Serial Coordination</u>

English also has a coordinate compound construction which exhibits flat structure only; it is illustrated in (36).

(36) Bill, Ilse or Chuck

In this construction, which we call serial coordination, the coordinator appears between the last two conjoins only, while (in written English) a comma, or under certain conditions, a semicolon, separates the other conjoins. Ignorning punctuation, we can account for serial coordination by adding to the grammar in section 2 the schema in (a").

(a") NP --> NP (NP)* CNP

The coordinator that appears between the last two conjoins is understood as connecting all of the conjoins in the construction; thus (36) is logically equivalent to (37) (with flat structure).

(37) Bill or Ilse or Chuck

Serial coordinate structures may enter into larger constructions, as in the following examples.

(38) Bill and Ilse, Terry or Chuck

(39) Bill, Terry and Ilse or Chuck

(40) Bill and Ilse; Chuck, Terry or David; and Cathy, Arnold and Mike

(41) Bill and Ilse; Chuck; Terry; or David and Cathy, Arnold and Mike

Example (38) may be read in two different ways, depending on whether Bill and Ilse occurs as a phrase in it (this would be indicated in speech by the absence of an intonational boundary between Bill and and). If it does, then the example as a whole is understood as a disjunction of three things: Bill and Ilse, Terry, and Chuck. If it doesn't, then the phrase is understood as the conjunction of two things: Bill and Ilse, Terry or Chuck. Similarly, example (39) may also be read in two different ways, this time depending on whether Terry and Ilse appears as a phrase in it. Next, example (40), as punctuated, is unambiguously interpreted as a conjunction of the three phrases separated by semicolons. If the first semicolon were replaced by a comma, then the phrase Bill and Ilse would be construed as the first of the disjuncts ending with David Finally, example (41), as punctuated, is unambiguously interpreted as a disjunction made up of the four parts Bill and Ilse, Chuck, Terry, and David and Cathy, Arnold and Mike.

The distinctive use of the punctuation marks in serial coordination in written English to some extent parallels the use of intonational cues to distinguish among various interpretations of ordinary coordination in spoken English. Moreover, the judicious combination of commas and semicolons in serial coordination is able, under certain circumstances, as in (41), to indicate up to two degrees of embedding, but no more. If the comma and the semicolon are used together, then the semicolon may be used to indicate the first level of embedding, and the comma to indicate the second level. I do not believe, however, that examples of serial coordination, like (41), can also be spoken so as to indicate the double embedding of coordinate structures.

6. Conclusions

The treatment of coordinate compounding by means of simple phrase-structure rules predicts much more amphibology than is in fact found in natural-language coordinate structures. Coordinate compounding in English without the use of correlative markers such as either and both is limited to one degree of embedding, except under special circumstances

involving serial coordination, in which it is limited to two degrees of embedding.[6] Thus the degree of amphibology in coordinate compound structures is expressed by neither the Catalan numbers discussed in Section 1, nor the generalized Catalan numbers discussed in Section 2, but (ignoring the possibility of double embedding in serial coordination) by one less than 2 raised to the power of one less than the number of conjoins. In careful spoken English, moreover, no coordinate compound expression of the type under discussion here is structurally ambiguous, since the structure can be uniquely indicated by the intonational phrasing.

The restriction against multiple embedding of coordinate compound structures can be expressed directly by means of a finite-state grammar, or by means of an augmented phrase-structure grammar that keeps track of the degree of embedding of coordinate compound structures. If the grammar is also permitted to perform the structure building characteristic of the algorithm that associates tree diagrams with derivations, then an elegant statement of the rules of grammar needed to characterize the structures of coordinate compounds can be achieved, without the need for rule schemata (cf. Jensen in press). Thus, the time-honored Chomskyan strictures against the tracking of derivations and against structure building (cf. Chomsky 1965) by phrase-structure rules have prevented linguists until now from achieving adequate characterizations of a wide range of linguistic phenomena.

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[6] The limitation on embedding of coordinate compounds is inconsistent with the principle of coordinate compounding discussed in Langendoen and Postal (1984), which is necessary to our demonstration that the collections of expressions of a natural language is a proper class. However, the limitation does not affect our demonstration that the number of expressions of English is of the order of the continuum, and hence nondenumerable.

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