Preposition—Phrase Attachment in Noun Phrases

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This paper examines the ambiguity of noun phrases (NPs) with postmodifying preposition phrases (PPs), such as "the triangle next to the circle below the square." This ambiguity is attributable in part to the difference in attachment sites for the second PP. If it attaches low, it modifies just the NP that is the object of the first preposition, and the resulting structure is right branching. If it attaches high, it modifies the entire preceding NP, and the resulting structure is left branching. However, each of these structures itself has two distinct interpretations. In the case of the high-attachment structure, these different interpretations have been previously noted; we call them stacking and coordinating. In the stacking interpretation, each PP modifies the entire NP to its left, whereas in the coordinating interpretation, it modifies just the head noun to its left (the first noun in the construction). In the case of the low-attachment structure, only the interpretation corresponding to the coordinating one has been noted; we call it alternating. However, a fourth distinct interpretation is possible, which corresponds to the stacking interpretation of the high-attachment structure; we call it stuffing. In the alternating interpretation, each preposition has scope only over the head of the NP that is its complement. In the stuffing interpretation, each preposition has scope over its entire complement. In a pilot study, we found that the interpretations based on low attachment are preferred to those based on high attachment by a 2:1 ratio. Of the two low-attachment interpretations, alternating is preferred to stuffing by a 20:1 ratio. However, of the two high-attachment interpretations, coordinating is preferred to stacking by only a 2:1 ratio. In a second pilot study, we examined the pattern of interpretations

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of phrases with four PP postmodifiers of an NP, which in principle have 112 distinct interpretation types. Eleven of these types were noted in the experimental materials. We provide a detailed analysis of these types and note that the relative preference of the various interpretations found in the first study is preserved.

INTRODUCTION

This study examines what is perhaps the very simplest problem of preposition-phrase (PP) attachment in English: the association of locative PP adjuncts with nouns (Ns) and noun phrases (NPs), as illustrated in (1).

(1) the triangle next to the circle below the square

This association is not widely viewed as problematic; most of the attention in the vast literature on PP attachment has focused on the more complex problem of the ambiguity of PP attachment to nouns versus PP attachment to verbs (Vs) and verb phrases (VPs), as in (2) (see Church & Patil, 1982, for discussion).

(2) Janet put the triangle next to the circle below the square.

However, (1) also manifests an attachment-site ambiguity. The PP *below the square* in (1) may be construed as a modifier either of the N *circle* (low attachment) or of the N *triangle* (high attachment). Thus, this construction can be used, as the more complex ones have been, to study attachment preferences in ambiguity resolution. Indeed, we may expect to get results in this domain that more accurately reflect attachment preferences per se, since the attachment sites are all of the same grammatical category, and the phrases being attached are all in the same relation to that category.

GRAMMARS AND INTERPRETATIONS

In order to frame hypotheses about attachment preferences, we need to provide a grammar that specifies the attachment possibilities, and we need to spell out the interpretations that correspond to the resulting structures.

Grammars

In (3), we give a simple phrase-structure grammar that provides two attachment sites for the second PP in (1), as shown in (4) and (5).

(3) a. NP → NP PP   d. N → {triangle, . . . }
     b. NP → DET N   e. P → {next to, . . . }
     c. PP → P NP   f. DET → the

(4)

the   triangle   next to   the   circle   below   the   square

(5)

the   triangle   next to   the   circle   below   the   square
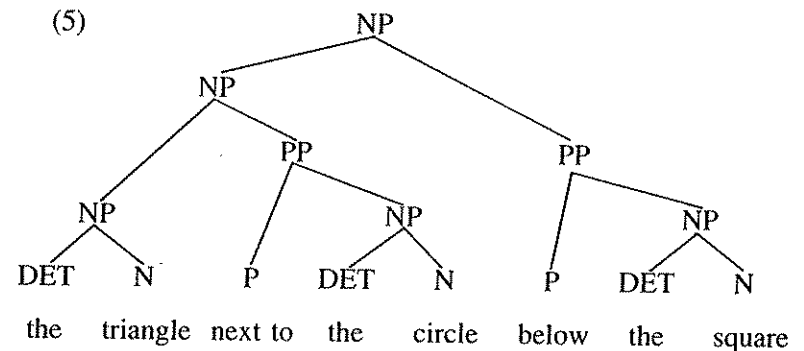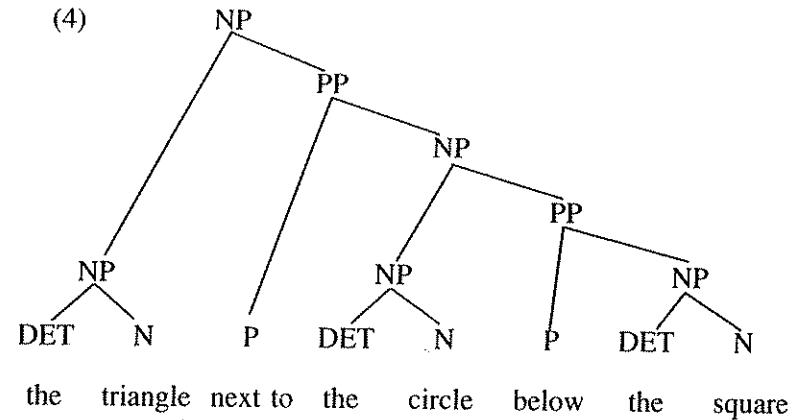
The phrase marker in (4), in which the PP below the square is attached low, exhibits *right recursion* of the NP node; while the phrase marker in (5), in which the PP below the square is attached high, exhibits *left recursion* of that node. Other grammars besides the one given in (3) could also explicate the ambiguity of (1). For example, the grammar in (6), in which the left-recursive node is N' instead of NP, in accordance with the X-bar theory of phrase-structure grammar, assigns somewhat different structural descriptions to (1) but explicates its ambiguity in essentially the same way. (In presenting the following grammars, we omit the counterparts to the lexical rules (3d–f).)

(6) a. NP → DET N'   c. N' → N
    b. N' → N' PP   d. PP → P NP

On the other hand, the grammars in (7) and (8) provide significantly different explications of the ambiguity of (1).

(7) a. NP → DET N' PP*   (8) a. NP → NP PP$^+$
    b. N' → N   b. NP → DET N
    c. PP → P NP   c. PP → P NP

In (7a), the asterisk following the PP indicates that any number (zero or more) of PPs may be sisters of an N'. Thus, the grammar in (7) has no left-recursive category; instead, PPs may simply be strung out as modifiers of a particular N. We say that the PP node exhibits *coordinate recursion*, though it should be noted that this grammar does not posit a single node that dominates all of the coordinate nodes; to do that would require yet another grammar. According to (7), the phrase in (1) has the structural descriptions shown in (9) and (10). The phrase marker in (9) is very similar in structure to that in (4), in which the second PP is attached low. The phrase marker in (10), on the other hand, is quite different from that in (5); however, in it, as in (5), the second PP is attached high.

(9)

the   triangle next to the   circle below   the   square

(10)

the   triangle next to the   circle   below   the   square
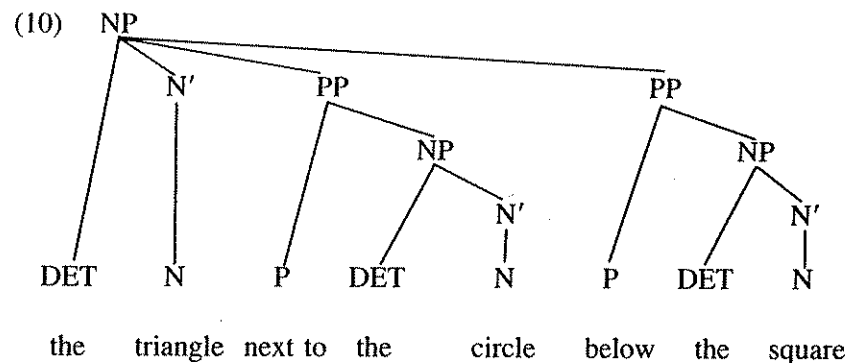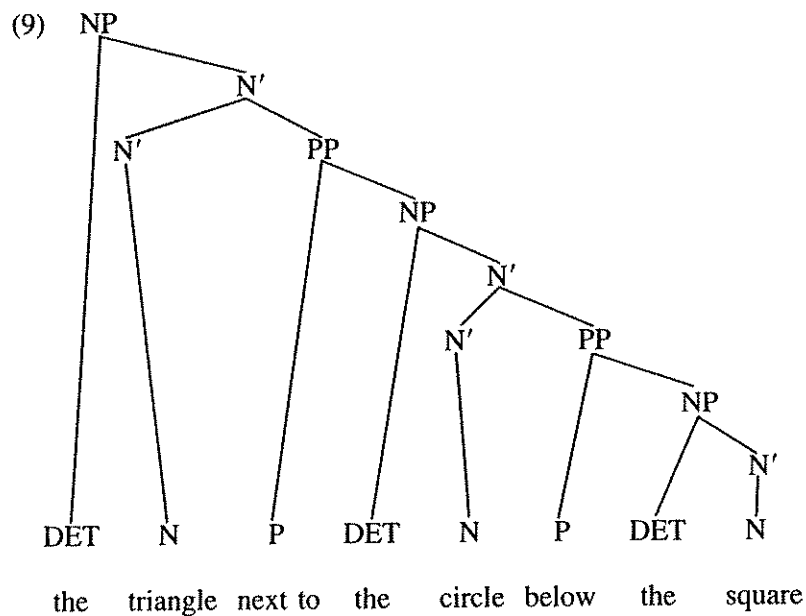
Turning to the grammar in (8), we note first that in (8a), the plus sign following the PP indicates that one or more PPs may be sisters of an NP. In this grammar, unlike that in (7), NP is both a left-recursive and a right-recursive node, but unlike that in (3), PP is also a coordinate node. According to (8), the phrase in (1) has three structural descriptions: (4), (5), and (11).

(11)

the   triangle   next to   the   circle   below   the   square
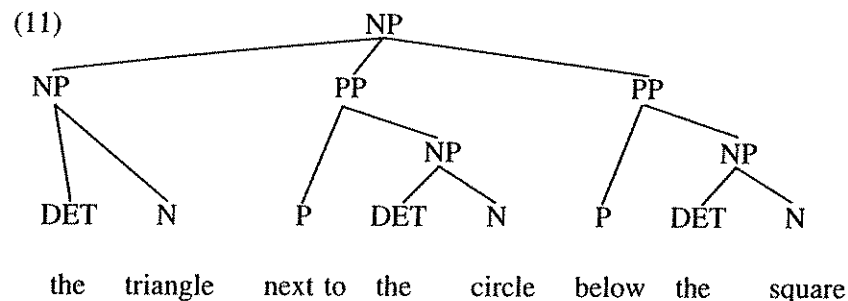
Note that in both (5) and (11) the second PP is attached high.

To summarize: Simple phrase-structure models of PP adjunction to Ns provide either two or three attachment-site possibilities for the second PP in (1), depending on whether the grammar provides for left and right recursion as in (3), right and coordinate recursion as in (7), or left, right, and coordinate recursion as in (8). We now turn to the question of determining how many interpretations phrases such as (1) actually have.

Interpretations

Clearly, (1) has at least two interpretations, one in which the second PP modifies the second N and one in which it modifies the first N. For each of these cases, we can further distinguish two subcases depending on which phrase a particular preposition occurring in it takes as one of its arguments. We call these four potential interpretations *alternating, coordinating, stacking,* and *stuffing.* We describe each of them in turn.

An interpretation of a phrase like (1) is alternating if each PP modifies just the noun that immediately precedes it. In the alternating interpretation of (1), the triangle is next to the circle and the circle is below the square, as shown in (12).

(12) □
     ○△
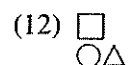
An interpretation is coordinating if each PP modifies just the initial noun. In the coordinating interpretation of (1), the triangle is next to the circle and the triangle is below the sqaure, as shown in (13).

(13)   □
     ○ △
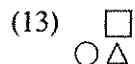
An interpretation is stacking if each PP modifies the entire phrase (N' or NP, depending on the grammar) that precedes it. In the stacking interpretation of (1), the triangle is next to the circle and the figure made up of the triangle next to the circle as a whole is below the square, as shown in (14).

(14) □
     ○△
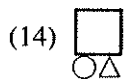
Finally, an interpretation is stuffing if the entire phrase following a particular noun modifies that noun. In the stuffing interpretation of (1), the circle is below the square and the triangle is next to the figure made up of the circle below the square as a whole, as shown in (15).

(15) □ △
     ○
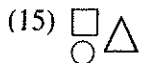
A PILOT STUDY

To determine whether a phrase like (1) is interpretable in each of these four ways, we undertook a pilot study in which we wrote out a phrase such as (1) at the top of a blank sheet of paper and asked each subject to draw a picture best corresponding to what she thought the phrase meant. There were 125 subjects, all high school students in a girls' yeshiva in Brooklyn, New York. The task was administered in classrooms; each subject received a sheet of paper with one of the two phrases in (16) written on it.

(16) a. the triangle next to the circle below the square
      b. the triangle below the circle next to the square

Subjects were instructed to draw the individual figures any size they liked, as long as the entire picture fit into the space provided, and to take as much time as they needed.

Of the 125 drawings that the subjects turned in, 6 contained mistakes of various sorts, and 13 were difficult to analyze in terms of the four possible interpretations described above. The remaining 106 drawings were easily analyzed as having the interpretations in (17).

(17) a. Alternating   68   (64%)   c. Stacking   12   (11%)
      b. Coordinating   23   (22%)   d. Stuffing   3   (3%)

Several observations are in order about these results. First, all four interpretations are possible. Second, the interpretations that are based on the juxtaposition of simple figures (alternating and coordinating) are far preferable to those that are not (stacking and stuffing); the relative proportion is about 9:1. Third, alternating is preferred to coordinating by about 3:1. Fourth, coordinating is preferred to stacking by about 2:1. Fifth, stacking is preferred to stuffing by about 4:1. Finally, alternating is preferred to stuffing by about 20:1.

A NEW GRAMMAR

None of the grammars that we have proposed for analyzing a phrase like (1) provide four distinct structural descriptions for it. However, it is pointless to attempt to formulate a simple phrase-structure grammar to do so. To see this, and to see what kind of grammar is needed to render the necessary distinctions, let us consider in detail how the structures that the

various proposed grammars assign to the phrase may be related to its interpretations.

First, it seems natural to relate the coordinating interpretations with one of the structures manifesting coordinate recursion, either (10), provided by the grammar in (7), or (11), provided by the grammar in (8). Second, the stacking interpretation is most naturally related to the structure in (5), which manifests left recursion. Finally, the stuffing interpretation is most naturally related to the structure in (4), which manifests right recursion. Curiously, the one interpretation that lacks an obvious structure to pair it with is the one that is by far the most preferred—namely, the alternating interpretation. Furthermore, there is no simple phrase structure that we could assign to (1) that would naturally be interpretable directly as alternating, since the medial phrase *the circle* under the alternating interpretation has a double function: It serves both as the object of the preceding preposition *next to* and as the subject of the following preposition *below*.

There is a phrase marker that one may reasonably associate with the alternating interpretation of (1), even though it cannot be directly interpreted as such—namely, one manifesting right-recursive structure, such as (4). However, (4) would then have two interpretations, one direct (stuffing) and one indirect (alternating). It might be thought that the alternating interpretation could be associated with a structure obtained from (4) by the application of a readjustment rule (Langendoen, 1975), but the structures that result from the application of such a rule would not naturally be interpretable as alternating. If anything, they are most naturally interpretable as coordinating.

To obtain the alternating interpretation of (1) from the phrase-marker (4), it is not necessary to adjust its structure. Rather it suffices to add a rule of interpretation in conjunction with rule (3c) (or its counterpart in the other grammars) that says that if the P referred to in that rule is in construction with a complex NP (an NP that itself contains a modifying PP), the object of that P may simply be the head of that NP, rather than the entire NP.

Such a rule is relatively easy to state in an enriched theory of phrase-structure grammar such as GPSG (Gazdar, Klein, Pullum, & Sag, 1985), which augments the categories of the simple theory of phrase-structure grammar with relational attributes such as SUBJECT, OBJECT, and HEAD, and which provides the ability to refer to and to assign those attributes in accordance with general principles. Furthermore, within that framework, it is also relatively easy to posit a complementary rule of interpretation in conjunction with rule (3a)—namely, that if the NP that is in construction with a PP is complex (i.e., itself contains a modifying

PP), then the subject of that PP may simply be the head of that NP. With such a rule, we are able to account for the coordinating, as well as the stuffing, interpretation of (1) using the left-recursive structure in (5). This means that we do not need to posit the coordinate-recursive structures in (10) and (11) to account for the coordinating interpretation, and that we can eliminate grammars containing infinite rule schemas, such as (7) and (8). In the following discussion, we assume an appropriately augmented version of the simple phrase structure grammar in (3), which we call (3A). However, we could equally well have chosen as the basis for augmentation any simple phrase structure grammar that provides both left- and right-recursive structural descriptions for phrases like (1).

To see how the alternating interpretation can be associated with the right-recursive structure in (4) and how the coordinating interpretation can be associated with the left-recursive structure in (5), consider the annotated phrase markers in (18) and (19).

(18)

the   triangle next to   the   circle   below   the   square

(19)

the   triangle next to   the   circle   below   the   square
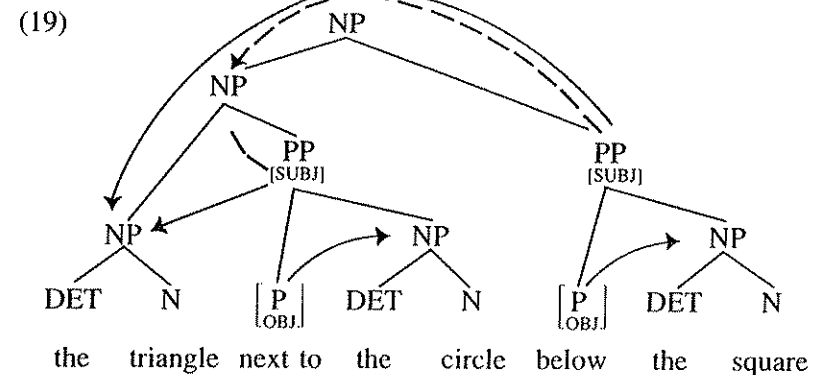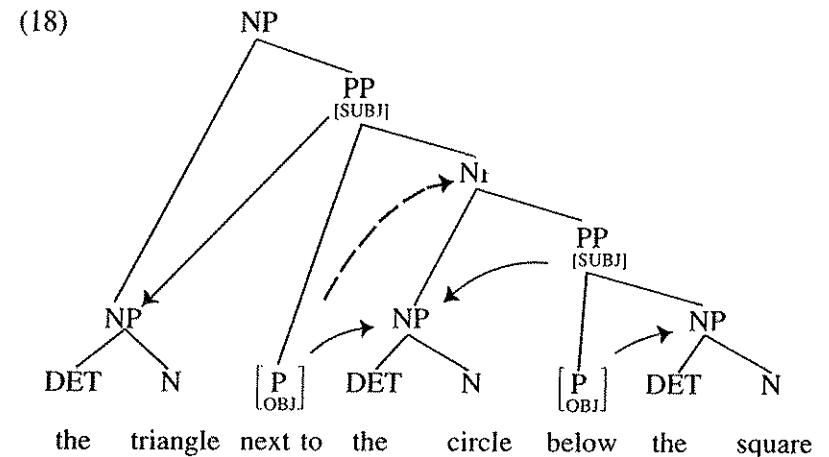
In (18)–(19), the OBJECT attribute of a P is a pointer either to the NP with which it is in construction or to the NP which is specified as the HEAD of that NP. For every P in (18)–(19), except for *next to* in (18), there is only one NP that is a candidate OBJECT. However, for this P, either *the circle* or *the circle below the square* is a candidate OBJECT. If the first is selected, then the alternating interpretation of (1) is obtained. If the second is selected, then the stuffing interpretation of (1) is obtained. Similarly, the SUBJECT attribute of a PP is a pointer either to the NP with which it is in construction, or to the NP which is specified as the HEAD of that NP. For every PP in (18)–(19), except for *below the square* in (19), there is only one NP that is a candidate SUBJECT. However, for this PP, either *the triangle* or *the triangle next to the circle* is a candidate SUBJECT. If the first is selected, then the coordinating interpretation of (1) is obtained. If the second is selected, then the stacking interpretation of (1) is obtained. For convenience, we refer to the alternating and coordinating interpretations as head-interpretations and the stuffing and stacking interpretations as phrase-interpretations.

A Combinatorial Explosion of Interpretations

As Church and Patil (1982) point out for the simple phrase structure grammars that they use to study attachment ambiguity, the degree of ambiguity that (3A) associates with any phrase it analyzes grows exponentially with the number of its subphrases (its PPs plus the initial NP). Let n be the number of subphrases of a particular phrase S. Then the number of interpretations $I(n)$ of S is given by the formula in (20), where Cat(n) is the nth term in the Catalan series, given by the formula in (21).

(20) a. $I(1) = 1$
     b. $I(n) = 2^{n-2}$ Cat(n) (for $n > 1$)

(21) Cat$(n) = \dbinom{2n}{n} - \dbinom{2n}{n-1}$

In (22), we give the first six values of $I(n)$.

(22)

n	$I(n)$	n	$I(n)$
1	1	4	20
2	1	5	112
3	4	6	672

The formula in (20) is arrived at as follows. The degree of structural ambiguity of a phrase S with n subphrases as analyzed by (3) is Cat(n). In each structure with one or more PPs, a choice has to be made for all but one of those PPs as to its SUBJECT attribute or the OBJECT attribute of its P. Since these choices are independent, the total number of choices that can be made is 2^{n-2}. (Recall that the number of PPs in S is $n-1$.)

From (22), we see that a phrase with five subphrases (four PPs) such as (23) has 112 interpretations with respect to (3).

(23) the triangle next to the circle below the square beside the diamond above the star.

ANOTHER PILOT STUDY

Obviously, when native English speakers encounter a phrase such as (23), they are quite unaware of its multiplicity of possible interpretations. To determine what interpretations they in fact come up with for such phrases, we conducted another study involving 104 different high school students from the same girls' yeshiva in Brooklyn, this time asking each of them to draw a picture best corresponding to a phrase of the form (24).

(24) the diamond P1 the triangle P2 the star P3 the circle P4 the square

In the position of P1 was one of the Ps {*above, below*} in the position of P2 was {*next to, beside*}; in the position of P3 was the other of {*above, below*}; and in the position of P4 was the other of {*next to, beside*}. Thus, there were eight different stimuli in all.

Of the 104 drawings, 15 contained errors or were incomplete, and 7 were of questionable interpretation. This left 82 drawings that were fully and, we believe, unambiguously interpretable. Of these 82, 65 (79% of the interpretable total) made consistent use of a single interpretation; that is, each prepositional relation was of the same type as each of the others. In (25), we give the numbers of drawings that consistently made use of a particular interpretation.[5]

(25) a. Alternating   46   (71%; 56%)
     b. Coordinating   18   (28%; 22%)

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[5]In parentheses, we give first the percentage of the total number of responses that showed consistent use of a single interpretation, followed by the percentage of the total number of interpretable responses.

c. Stacking   1   (1%; 1%)
d. Stuffing   0   (0%; 0%)

Comparing the figures in (25) with those in (17), we note that the relative proportion of subjects who employed the alternating interpretation exclusively to those who employed a coordinating one exclusively remained roughly 3:1. However, the number of subjects who consistently used a phrase-interpretation exclusively essentially dropped to zero.

The remaining 17 (21%) of the interpretable drawings made use of at least two different interpretations. Of these, all but 1 made use of exactly two; the remaining 1 made use of three. However, besides analyzing the number of different interpretations used, it is important to analyze the numbers and types of *shifts* in interpretation between adjacent Ps. A summary is provided in (26).

(26) a. Coordinating → Alternating   5   (29%; 6%)
     b. Stacking → Alternating   5   (29%; 6%)
     c. Stacking → Stuffing   2   (12%; 2%)
     d. Alternating → Stacking   1   (6%; 1%)
     e. Stacking →Alternating → Stacking   1   (6%; 1%)
     f. Coordinating → Stuffing → Stacking   1   (6%; 1%)
     g. Alternating → Stacking → Alternating 1   (6%; 1%)
     h. Alternating → Stuffing → Alternating 1   (6%; 1%)

From (25) and (26), we see that the number of distinct interpretations that were assigned to the stimuli phrases is 11 (10% of the possibilities), but only 4 interpretations (4% of the possibilities) were exemplified by more than two drawings. Of these 4 interpretations, 3 (25a,b) and (26a) involved a head-interpretation only, and these accounted for 71 (87%) of the interpretable drawings. Thus, we may conclude that when the number of PP modifiers of Ns is increased, the preference for head-interpretations is strengthened.

This conclusion is supported by a detailed examination of the shifts in interpretations that are given in (26). Assuming that a subject draws the individual figures in the order in which they are presented in the stimulus,[6] we note that if a subject starts by relating the figures using a

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[6]We did not, in fact, observe how any of the subjects drew the figures, nor did we interview any of them after the study was completed, but in our informal presentation of our materials to colleagues, we have noted that this is how they do it.

head-interpretation, they tend to use the same interpretation throughout the task, but if they start by using a phrase-interpretation, they tend to shift to another interpretation later on. In (27), we present for each interpretation on an individual medial P or PP the number of times the interpretation on the next P or PP was the same or different (i.e. whether a shift in interpretation occurred), and the percentage of shifts.

(27)

Interpretation	Nonshift	Shift	% Shift
a. Alternating	102	4	4
b. Coordinating	37	6	14
c. Stacking	3	9	75
d. Stuffing	2	2	50
Totals	144	21	13

The tendency to avoid shifting interpretations within a complex ambiguous construction has already been noted by Krauwer and des Tombe (1981). (Their term for shifting is *skating*.) We note further that when a shift did occur, it tended to be the alternating interpretation, and more generally to a right-recursive interpretation (alternating or stuffing). In (28), we tabulate the shifts that were made according to the interpretation that was shifted to.

(28) a. Shift to Alternating   13   (62%)
          i. from Stacking   7
         ii. from Coordination   5
        iii. from Stuffing   1
     b. Shift to Stuffing   4   (19%)
          i. from Stacking   2
         ii. from Alternating   1
        iii. from Coordinating   1
     c. Shift to Stacking   4   (19%)
          i. from Alternating   3
         ii. from Stuffing   1
     d. Shift to Coordinating   0   (0%)

From the information in (25) and (26) it is possible to determine the total number of drawings in which each of the interpretations occurred at least once. This tabulation is given in (29).[7]

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[7]The percentages add up to more than 100% because more than one interpretation was used in particular drawings. Fortuitously, however, the total number of interpretations does add up to 100.

(29) a. Alternating   60   (73%)   Stacking   12   (15%)
     b. Coordinating   24   (29%)   Stuffing   4   (5%)

When we compare (29) with (17), we see that the tendency of subjects to use particular interpretations in carrying out the task of drawing figures that correspond to NPs with modifying PPs remains relatively stable with different numbers of PPs.

CONCLUSIONS

Let us continue to consider a grammar like (3) to be the basis of the construction of NPs with PP modifiers in English, in which right recursion is used to support the alternating and stuffing interpretations of those phrases and left recursion is used to support their coordinating and stacking interpretations. We may then conclude, first of all, that the standard finding initially formulated in Kimball's classic paper on the subject (1974) that interpretations based on right recursion are preferred to those based on left recursion in language comprehension when both are available is strongly supported. We have further established that in semantically and syntactically neutral contexts, right recursion (low attachment) is preferred to left recursion (high attachment) by about a 3:1 margin. Furthermore, there is a tendency in processing complex phrases in which a series of judgments must be made about attachment to stay with whatever choice one makes at the beginning of a phrase, but if one does shift, then there is a strong tendency to shift from left recursion to right recursion rather than vice versa. From (28), we see that 17 of the 21 shifts (81%) reported above were from high attachment to low attachment. This observation lends further support to the standard view that right recursion is preferred to left recursion whenever both are available.

Second, regardless of whatever attachment is made, there is a strong tendency to provide a head-interpretation for it, rather than a phrase-interpretation. This tendency strengthens as the number of subphrases increases. Moreover, if the structure is right recursive, there is an overwhelming tendency to give it a head-interpretation (alternating, rather than stuffing). This fact may explain why the stuffing interpretation for complex modifier constructions has not been noticed until now,

whereas the stacking interpretation is well known, especially in the case of relative-clause modifiers (Jackendoff, 1977).[8]

The relative accessibility of the stacking interpretation compared with that of the stuffing interpretation is easily explained. When we compare the stacking interpretation of (1) with its coordinating interpretation (both based on high attachment of the second PP), we see that we have to establish a nonlocal relation between the beginning of the phrase (the first NP) and the second PP in both cases. All that the stacking interpretation requires in addition is the information contained in the intervening PP. On the other hand, when we compare the stuffing interpretation of (1) with its alternating interpretation (both based on low attachment of the second PP), a big difference emerges. Under the latter interpretation, the object of the first P can be determined locally; it is the immediately following simple NP. Under the former interpretation, the object of the first P cannot be determined locally; it is the entire following complex NP. Thus, we may expect that the stuffing interpretation will always be highly disfavored compared with the alternating interpretation, whereas the degree to which the stacking interpretation will be disfavored with respect to the coordinating interpretation will diminish gradually with the number of PPs that intervene between the initial NP and the PP being processed.

APPENDIX: The Distinction Among the Four Types of Interpretation

In this appendix, we provide a demonstration that the four types of interpretation that we provide for examples like (1) are in fact distinct. The type of example we need to show this has one occurrence of a vertical relation such as *below*, which we assume to mean 'right below,' followed by three occurrences of a horizontal relation such as *next to* or *beside*, which we take to be synonyms and to mean 'right next to' or 'right beside'; or one occurrence of a horizontal relation followed by three occurrences of a vertical relation. Such an example is given in (30).

(30) the diamond below the triangle beside the square next to the circle beside the star

In (31)–(34) we provide diagrams consistent with (30), each of which satisfies one and only one of the four interpretation types. In the case of the diagram satisfying the coordinating interpretation, one of the figures is of necessity superimposed on another. These figures are to be construed as right beside each other in a third dimension.

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[8]Jackendoff argues, however, that what linguists refer to as the stacking interpretation for relative-clause constructions is really a coordinating interpretation, and that the apparent effect of stacking is due to the interaction of focus and presupposition with the coordinating interpretation. Whether or not this is correct for relative clauses, it is not correct for PP modifiers.
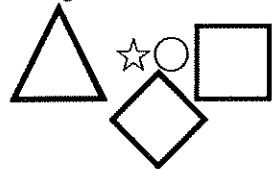
(31) Alternating

(32) Coordinating

(33) Stacking

(34) Stuffing

Now consider the propositions in (35). Each of the diagrams (31–34) can be evaluated for their truth or falsity. The results are shown in (36).

(35) (a) the circle is beside the star
     (b) the diamond is beside the star
     (c) the square is beside the triangle

(36) Proposition:	(35a)	(35b)	(35c)
(a) Alternating (31)	T	F	T
(b) Coordinating (32)	F	T	F
(c) Stacking (33)	F	F	T
(d) Stuffing (34)	T	F	F

As (36) reveals, each of the four interpretation types can impose a different pattern of truth and falsity of the propositions in (35). We conclude therefore that the four interpretation types are indeed distinct.

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A Psychological Perspective on Intonational Grouping

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The empirical bases for some of the tenets of metrical phonology are discussed in light of acoustical studies of speech intonation. The results suggest that a rigorous coupling of theory and experimentation is required for progress in unraveling the mental representations and processes that mediate intonational patterns.

The work that I have conducted collaboratively with a number of colleagues suggests that a major proportion of the phrasal effects on intonation, particularly those accompanying the beginnings and ends of major constituents, can be handled by a theory that makes direct reference to an internalized phrase structure grammar, required independently to account for a variety of nonintonational phenomena, including constraints on speech exchange errors, constraints on phrase movement and deletion, and the operation of external sandhi rules. I will not review this body of research here since it is presented elsewhere (e.g., Cooper, Paccia, & Lapointe, 1978; Cooper, Egido, & Paccia, 1978; Danly & Cooper, 1979; Cooper & Paccia-Cooper, 1980; Cooper & Sorensen, 1981), the theory being summarized in Chapter 7 of the 1980 book. Instead, I would like to comment on the level of empirical support for the highly complex sorts of phonological representations posited by Selkirk (1984) and others that emerge from work in metrical phonology (see also Cooper, 1986).

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