Argumenthood and English Prepositional Phrase Attachment

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Two self-paced reading experiments are presented to assess how temporary ambiguities in prepositional phrase attachment are resolved in English verb–noun-phrase–prepositional-phrase sequences. The hypothesis tested is a preference to maximize argument relations, in contrast to an overall verb phrase attachment preference (cf. Minimal Attachment). Five syntactic argumenthood diagnostics were used to construct noun phrase argument and verb phrase modifier completions of sentences, differing by one word and controlled for frequency. It was found that (1) noun phrase argument completions were read significantly faster in the disambiguating region and (2) unambiguous verb phrase modifiers were read as quickly as noun phrase arguments and faster than ambiguous verb phrase modifiers. These results suggest that argument relations are maximized in initial comprehension of the target ambiguity. Alternative potential explanations for the findings are evaluated, including a recency-based account and a lexical-frequency treatment.   © 1999 Academic Press

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A syntactic ambiguity that has figured prominently in the development of theories of sentence comprehension involves the possible attachments of prepositional phrases (PPs) in verb–noun-phrase–prepositional-phrase (V-NP-PP) sequences, as exemplified by the sentences in (1).

(1) (a) The spy saw a cop with a telescope.
    (b) The spy saw a cop with a revolver.

In sentence (1a), the PP *with a telescope* can be taken to modify the act of seeing, describing the instrument the spy used (a verb phrase (VP) attachment reading) or to modify the cop, describing what the cop was holding (an NP attachment reading). Sentences of this form are usually not globally ambiguous; for example, in (1b) our knowledge of the real world dictates that revolvers cannot be used for seeing, and so the NP attachment reading is forced. But since prepositions like *with* can be used in numerous ways, an incremental parser often cannot determine which attachment of a PP will be appropriate until a disambiguating word (e.g., *revolver*) has been encountered. On the assumption that a structure and an interpretation is assigned to incoming material word-by-word (Marslen-Wilson, 1973, 1975; Tyler & Marslen-Wilson, 1977; Swinney, 1979; Shillcock, 1982; Garrod & Sanford, 1985; Tanenhaus, Carlson, & Seidenberg, 1985; among others), researchers have proposed several alternative answers to the question of how structure is

assigned to an incomplete sentence like *The spy saw the cop with...* (Rayner, Carlson, & Frazier, 1983; Taraban & McClelland, 1988; Altmann & Steedman, 1988; Clifton, Speer, & Abney, 1991; Britt, Perfetti, Garrod, & Rayner, 1992; Britt, 1994; Spivey-Knowlton & Sedivy, 1995; cf. Konieczny et al., 1997, and works cited there for German; Frazier, 1987, for Dutch; Pynte & Prieur, 1997, for French; Igoa, 1995, for Spanish). For example, Rayner, Carlson, and Frazier (1983) took an apparent preference for VP attachment to support Minimal Attachment (Frazier, 1978), a structural principle sensitive only to the number of nodes in syntactic trees. Using a different range of V-NP-PP examples, Abney (1987, 1989) proposed an argument preference strategy, which appeals to a general syntactico-semantic property of the relationships among constituents of a sentence; we discuss the nature of argumenthood in detail below. However, Clifton, Speer, and Abney (1991) provided experimental evidence against Abney's proposal as an initial-choice algorithm for ambiguity resolution, instead reaffirming Minimal Attachment. More recently, V-NP-PP ambiguity resolution has been claimed to provide evidence for constraint-based/lexicalist/frequentist approaches (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Sedivy & Spivey-Knowlton, 1994; cf. Ford, Bresnan, & Kaplan, 1982), some of which eschew general structure-based principles altogether in favor of frequency information about particular lexical items or lexical classes and "content-based expectations" (Taraban & McClelland, 1988, 1990). Each of these accounts makes different predictions about how the ambiguity should be resolved across the full range of examples.

In this paper, we present new experimental evidence relevant to Abney's hypothesis that the processor initially favors *argument* attachments over *modifier* attachments,[1] in contrast to Clifton et al.'s claim that the processor follows an initial syntactic-category-based preference. We view Abney's hypothesis as an elaboration of the constraint-based approach to sentence comprehension, according to which a variety of sources of information is brought to bear on the resolution of ambiguity, including lexical frequency, semantics, plausibility, and resource cost (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Garnsey, 1994). In particular, the preference for argument attachments is one way of formulating what Taraban and McClelland's "content-based expectations" are in terms of the lexically based hypothesis of MacDonald et al. and Trueswell et al., using the lexical semantics of the individual words to guide the parser's preferences. Adapting ideas from Jackendoff (1977, p. 57), Marantz (1984, p. 15), Pollard and Sag (1987, p. 136), and Grimshaw (1990, p. 108), we summarize our interpretation of the contrast between arguments and modifiers in (2).

(2) If a phrase P is an argument of a head H, P fills a role in the relation described by H, the presence of which may be implied by H. P's contribution to the meaning of the sentence is a function of that role and hence depends on the particular identity of H.

In contrast, if P is a modifier, it predicates a separate property of its associated head or phrase. Its semantic contribution is independent of other elements and hence is relatively constant across a range of sentences in which it combines with different heads.

In (3) we see the contrast manifested within NPs. In (3a), the head *student* implies the role of the thing being studied; the sentence tells us one property of John: that he studies physics. In (3b), *from Phoenix* predicates a separate property of the student; there is no head in the sentence that implies the presence of the role of geographical origin. The sentence as a whole describes two properties of John: that he is a student and that he is from Phoenix.

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[1] We deliberately avoid using the term *adjunct* in this paper because it also has a structural sense in linguistic theory, under which it might not necessarily be synonymous with *nonargument;* we use *modifier* as a cover term for nonarguments regardless of their structural position. Note that Clifton, Speer, and Abney (1991) use the term *modifier* to cover both arguments and nonarguments; that is not the sense used here.

(3) (a) John is a student of physics. [argument]

(b) John is a student from Phoenix. [modifier]

Now consider VPs. In (4a), *on Sunday* can be interpreted correctly without any reference to the rest of the sentence and has the same meaning with each verb. In contrast, *on Sandy* in (4b) can be interpreted only with reference to the verb; the meaning of this phrase is different across these sentences.

(4) (a) Kim {ate/was sad/broke her ankle} on Sunday. [modifier]

(b) Kim {depended/blamed the arson/ decided} on Sandy. [argument]

As a consequence of (2), arguments on the whole occur with a narrower range of heads than modifiers do, as shown in (5) and (6). (Here and below, an asterisk indicates ungrammaticality.)

(5) (a) a woman/dog/muppet/scarecrow/ android with gray hair [modifier]

(b) a member/*dog/*muppet/*scarecrow/*android of Parliament [argument]

(6) (a) John {died/sneezed/broke his arm/ saw Fred/laughed at Bill} in the afternoon. [modifier]

(b) John {informed/*saw/*hit/*admired/ *surprised} his friend of the danger. [argument]

Abney (1987, 1989) proposed argument preference as a disambiguation strategy based on intuitions about sentences like (7) (cf. related proposals by Pritchett, 1988; Gibson, 1987, 1991; Konieczny et al., 1997).

(7) I thought about his interest in the Volvo.

People prefer the interpretation where *in the Volvo* describes what he was interested in (the NP-attached reading), not where I did my thinking (the VP-attached reading). *In the Volvo* is an argument of the noun *interest,* but it is not an argument of the verb–preposition combination *thought about.* We refine Abney's idea in order to take account of the fact that argumenthood does not appear to be an all-or-nothing property of PPs; our proposal is given in (8).

(8) *Argument Preference Strategy:* In cases of attachment ambiguity, the parser prefers the attachment that maximizes the extent of the argument relation between the attaching phrase and the attachment site.

While the ideas in (2) are central to the notion of argumenthood, in particular cases it may be hard to arrive at clear intuitions on these semantic criteria. As a result, it has proved fruitful to appeal to several syntactic phenomena that correlate closely with those semantic notions. In Appendix A, we have assembled from the syntax literature relevant argumenthood diagnostics that were used in designing the stimuli for our experiments.

It should be noted that there are other ways to formalize a lexically based parsing proposal following MacDonald et al. and Trueswell et al. The approach we have started with here is a linguistically based lexical semantics proposal. Alternatively (and perhaps more in line with MacDonald et al.'s and Trueswell et al.'s proposed models), it could be that the processor is sensitive to frequencies of occurrences of similar structures that have been encountered in the past. It turns out that it is difficult to separate the lexical-semantics argument-based hypothesis proposed here from the frequency-based hypothesis with respect to the V-NP-PP ambiguity, because argument attachments appear to be much more frequent than modifier attachments in this construction; as a result, both theories make the same predictions with respect to most instances of this ambiguity. Our experiments therefore do not separate these hypotheses, but we suggest ways to do so in the General Discussion.

We should emphasize that we do not claim that any single factor determines initial parsing preferences; rather, we are simply testing whether the Argument Preference Strategy is one factor contributing to such decisions. There will surely be different degrees of attachment preference both among arguments and among nonarguments as well, including biases due to properties of particular words (cf. Konieczny et al., 1997, for instrumentals). There could even be instances where a modifier attachment is favored over an argument attachment, if other

factors outweigh the Argument Preference Strategy.

PREVIOUS FINDINGS

Rayner, Carlson, and Frazier (1983) conducted an eye-tracking study on 12 sentence pairs similar to (1), measuring first-pass reading times in the disambiguating region, and found that completions that are pragmatically more likely to be VP-attached, like (1a), were read faster than NP-attached completions like (1b). Based on this finding, Rayner et al. argued that initial VP attachment is always initially preferred, and they take this to be an instance of the more general parsing principle Minimal Attachment, stated in (9).

(9) *Minimal Attachment:* Attach incoming material into the phrase marker being constructed using the fewest syntactic nodes consistent with the well-formedness rules of the language. (Frazier & Rayner, 1982, p. 180)

However, because they did not control for the argument versus modifier status of their PPs, the generality of this finding remains open to question. By our criteria, 8 of their 12 items contrasted VP-attached arguments with NP-attached modifiers.

It is important to note that a preference for VP over NP attachment in V-NP-PP sentences follows from Minimal Attachment (9) only under certain specific assumptions about phrase structure (see Frazier, 1990, for discussion). In particular, it is crucial that the node under which the PP could be attached already exists in the VP but must be added to the NP. To see why this is so, consider the four possible pairwise attachment choices.[2] The structures assumed by Clifton et al. are shown in Fig. 1.

1. *Argument of V versus argument of N:* Minimal Attachment would prefer V over N attachment only if V attachment involved adding fewer nodes than N attachment. (If the same number of nodes were required for each attach-
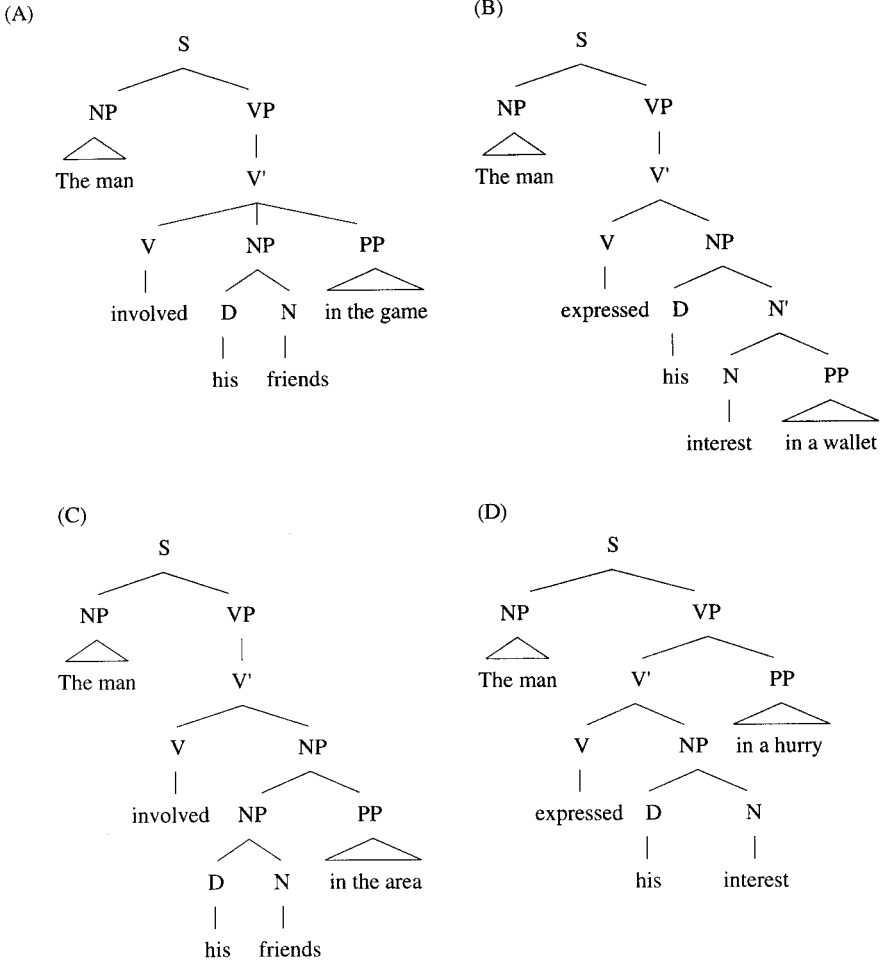
ment, then Minimal Attachment would make no prediction, but Late Closure (Frazier, 1978) or a recency/locality preference would predict an NP attachment preference.) This would be true if N′ had not yet been built prior to attachment of the PP, while V′ had been. Under certain theories of phrase structure (e.g., Speas, 1994; Chomsky, 1995; cf. Frazier, 1990), the direct object noun is an immediate daughter of NP (i.e., it is the highest node below the NP node) when it is first attached (cf. Fig. 1A), and N′ must be added in order to attach an argument of N, as in Fig. 1B. In addition, attaching the PP argument to VP must require *no* extra nodes to be built. This could be true if ternary branching were permitted by the grammar (that is, if a tree node were allowed to have three daughter nodes rather than at most two, contra Kayne, 1984, inter alia), so that the PP argument following the direct object NP could be a sister of V and daughter of the already-constructed V′, as shown in Fig. 1A.

2. *Argument of V versus modifier of N:* Given the ternary branching assumption already needed for the previous case, attaching as an argument of V would be preferred over a modifier of N if adding an NP modifier involved adding at least one node. This extra node is needed if N modifiers are adjoined to NP, that is, attached by adding a new segment of the existing NP node, as shown in Fig. 1C. Alternatively, the preference for V over N attachment would also hold if a modifier had to be a sister of N′, because the requisite N′ node would not have been constructed yet and would have to be added.

3. *Argument of N versus modifier of V:* Under the above assumptions, the NP attachment will require exactly one new node, namely, N′, as in Fig. 1B. Thus, for this attachment to be dispreferred, adding a PP as a modifier of VP must require *no* new nodes to be constructed. Thus, it must not be true that VP modifiers are necessarily adjoined, otherwise a new VP node would be introduced (cf. Fig. 2D). Rather, it must be that VP modifiers can be sisters to V′, attached directly under the existing VP, as in Fig. 1D.

4. *Modifier of N versus modifier of V:* It was shown in case 2 that NP modifier attachment

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[2] We assume, along with Frazier (1990) and Clifton, Speer, and Abney (1991), that arguments must be sisters of their heads, where two nodes in a tree are sisters if they share a common parent node immediately above them.

(A)

```
                    S
           ┌────────┴────────┐
          NP               VP
          △                 │
      The man              V'
                   ┌─────────┼─────────┐
                   V         NP        PP
                   │        ╱  ╲        △
               involved    D    N    in the game
                           │    │
                          his  friends
```

(B)

```
                    S
           ┌────────┴────────┐
          NP               VP
          △                 │
      The man              V'
                   ┌─────────┴─────────┐
                   V                   NP
                   │                  ╱  ╲
              expressed              D    N'
                                     │   ╱  ╲
                                    his N    PP
                                        │    △
                                    interest in a wallet
```

(C)

```
                    S
           ┌────────┴────────┐
          NP               VP
          △                 │
      The man              V'
                   ┌─────────┴─────────┐
                   V                   NP
                   │                 ╱    ╲
               involved            NP     PP
                                  ╱  ╲     △
                                 D    N  in the area
                                 │    │
                                his  friends
```

(D)

```
                    S
           ┌────────┴────────┐
          NP               VP
          △             ┌───┴───┐
      The man          V'       PP
                     ┌──┴──┐     △
                     V     NP  in a hurry
                     │    ╱  ╲
                 expressed D  N
                          │   │
                         his interest
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FIG. 1. Structures assumed by Clifton et al. (1991): verb argument (A), noun argument (B), noun modifier (C), verb modifier (D).

must require at least one new node, as in Fig. 1C, and it was shown in case 3 that VP modifier attachment requires no new nodes, as in Fig. 1D. Therefore, the VP attachment will be preferred.

Thus, there are three critical assumptions required for Minimal Attachment to prefer VP over NP attachment in all situations: ternary branching must be allowed by the grammar, certain intermediate nonbranching categories must not be projected, and modifiers must be possible sisters to X′. Suppose instead one assumes a more traditional X-bar phrase structure (cf. Jackendoff, 1977) in which intermediate

categories must be projected and all phrasal modifiers must be adjoined, as in the structures in Fig. 2. (For simplicity we have omitted a phrasal DP projection for determiners in Fig. 2; although this would be required under a strict X-bar account, it does not affect the points under discussion.) Then Minimal Attachment would predict that VP arguments (Fig. 2A) are preferred over NP modifiers (Fig. 2C), but NP arguments (Fig. 2B) are preferred over VP modifiers (Fig. 2D). In both cases, an argument attachment makes use of an existing single-bar-level node, while a modifier attachment requires the addition of an XP. Thus, it is possible to
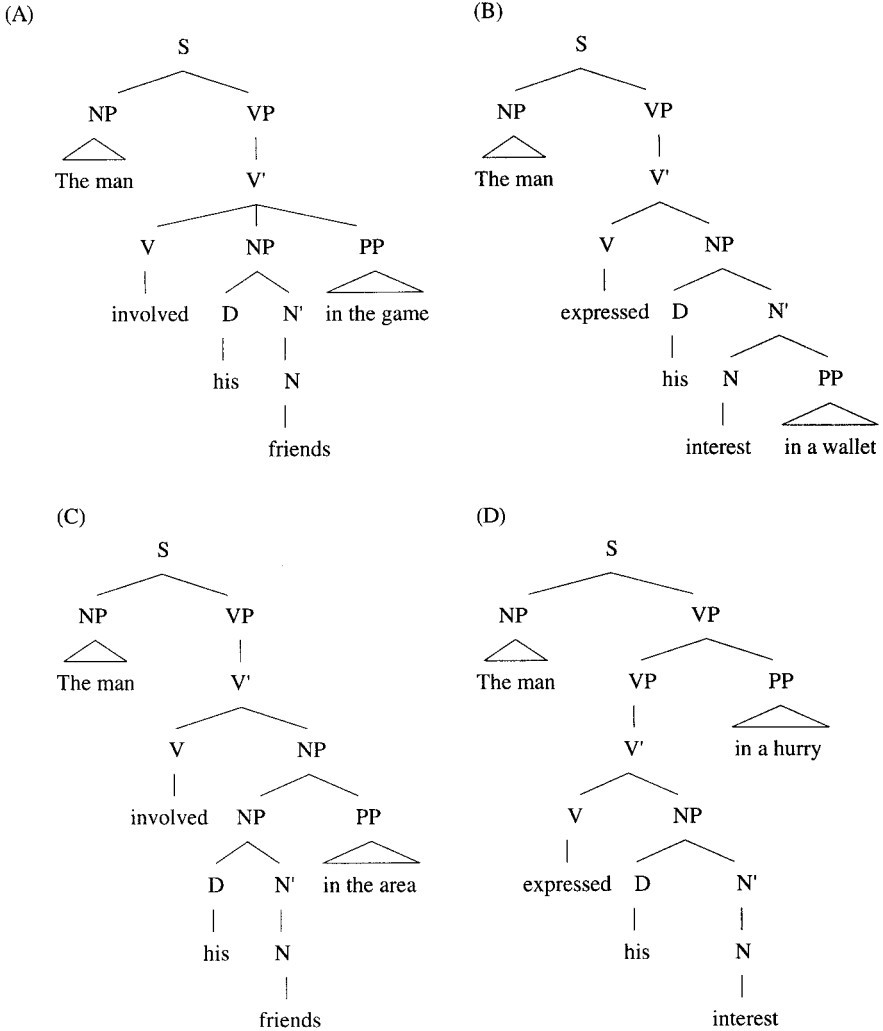
FIG. 2. Possible structures under traditional X-bar theory: verb argument (A), noun argument (B), noun modifier (C), verb modifier (D).

accept Minimal Attachment as a parsing principle but reject the particular phrase structure assumptions adopted by Clifton et al. from Frazier and her colleagues (Frazier & Rayner, 1982; Frazier, 1990), in which case an argument preference could be predicted for the V-NP-PP ambiguity. However, for clarity of exposition, in the remainder of the text we use "Minimal Attachment" to refer to the specific proposals made by Frazier and her colleagues. Of course, the trees in Figs. 1 and 2 do not exhaust the possible structures for these four sentence types. Because our proposal does not involve counting

nodes in trees, further exploration of these details is not relevant.

A number of studies subsequent to Rayner et al.'s have found a VP attachment preference for the V-NP-PP ambiguity: Ferreira and Clifton (1986), Clifton and Ferreira (1989), Britt et al. (1992), Rayner, Garrod, and Perfetti (1992), and Britt (1994). However, argumenthood was not controlled for in these studies. Thus, none of these studies can be taken as unequivocal support for a general VP attachment preference.

Taraban and McClelland (1988) demonstrated that the VP attachment preference ob-

tained in the sentences that Rayner et al. tested was not a general preference. In a word-by-word self-paced reading experiment, Taraban and McClelland replicated the VP attachment preference for Rayner et al.'s sentences, but found an NP attachment preference for a new set of 18 sentences exemplified in (10); that is, (10a) was read more quickly than (10b) in the disambiguating region.

(10) (a) The report described the government's programs in education.

   (b) The report described the government's programs in detail.

They concluded that PP attachment preferences are determined on the basis of all the information contained in the sentence up to that point, perhaps combined with people's knowledge of the world, and that no general syntactic preference exists:

> The results we have reported cannot be accounted for by *any* syntactic principle of which we are aware—that is, by any principle that does not consider the content of the sentence—since our expectation effects occurred in sentences that differed in the content, and not in the syntactic constituents of the sentence frames (Taraban & McClelland, 1988, p. 611; emphasis in original).

While Taraban and McClelland's findings are evidence against Minimal Attachment, these findings do not rule out other syntactic strategies, such as the Argument Preference Strategy. In particular, argumenthood was not controlled for; only two of Taraban and McClelland's 18 items contrasted a VP-attached argument with an NP-attached modifier, whereas six of their items contrasted an NP-attached argument with a VP-attached modifier.

Clifton, Speer, and Abney (1991) conducted experiments that were specifically designed to test the argument preference hypothesis. They contrasted NP versus VP and argument versus modifier attachments as in (11).

(11) *VP argument:*

   (a) The war alienated the young people *from the social system* and decreased voter turnout among the younger generation.

NP modifier:

(b) The war alienated the young people *from our neighborhood* and decreased voter turnout among the younger generation.

NP argument:

(c) The war increased alienation *from the social system* and decreased voter turnout among the younger generation.

VP modifier:

(d) The war increased alienation *from the beginning* and decreased voter turnout among the younger generation.

Using eye-tracking and phrasal self-paced reading, Clifton et al. found an initial VP preference, as measured by average reading time throughout the PP, but on the subsequent region (one or more words following the disambiguation) an argument attachment preference appeared. They took this result to support the Minimal Attachment claim that the first preference is always to attach to the VP. Furthermore, they concluded that Abney's hypothesis about a preference for argument attachments was true of a later, semantic, stage of parsing.

However, there are several problems with the interpretation of Clifton et al.'s findings. Some of these are pointed out by Konieczny (1996), who argued that an examination of all the eye-tracking measures reported, especially the combination of frequency of regression with fixation durations, strongly suggests a conclusion opposite to that of Clifton et al. Although Clifton et al. did not present all the data necessary for a comprehensive reanalysis, Konieczny made several plausible arguments for concluding that Clifton et al. actually found an *initial* preference for arguments over modifiers.

Clifton et al.'s materials also suffer from potential confounds. The relative plausibility of the different completions was not systematically controlled (Speer and Clifton, in press). Also, half of the crucial contrast pairs differed on the number of words (e.g., (12)) or the kind and amount of structure within the PP where the comparison was conducted (e.g., (13a), with the structures in (13b)). Thus, any differences in

reading time between PPs in the two versions of a sentence could be due to these extraneous differences rather than to the different syntactic attachments. Even when the number of words was matched, the PPs were sometimes idioms such as *in record time* (14), which might well be read quickly simply because they are recognized as units, in contrast to the nonidiomatic *in church affairs* (Swinney & Cutler, 1979).

(12) John continued the discussion with (persistence/the tired boys).

(13) (a) The teacher encouraged excitement over {the course of the week/learning to read}.

(b) [$_{NP}$ the [course [$_{PP}$ of [$_{NP}$ the week]]]] vs. [$_{NP}$ PRO [$_{VP}$ learning [$_{IP}$ PRO to [$_{VP}$ read]]]].

(14) Maria increased her involvement in {record time/church affairs}.

As for the argument/modifier status of the items, by the criteria used in constructing our materials, 12 of the 16 items did involve an NP argument contrasted with a VP modifier; three involved NP and VP arguments (items 1, 2, and 15), and one did not contain a preposition in the VP-attached completion (item 16). (See Schütze, 1995 for other potential problems with specific items.)

In a follow-up study, Speer and Clifton (in press) explored the apparent advantage for verb arguments over VP modifiers found by Clifton et al. and attempted to distinguish effects of argument status versus plausibility on reading times in V-NP-PP sentences. They found a significant argument advantage in reading times for low-plausibility items, which cannot be explained by plausibility as measured by their "sensibleness" ratings, because these did not differ significantly and were numerically in the opposite direction. Unfortunately, the relevance of this study to the construction of concern here is questionable, because 7 of the 20 items contained VP adjuncts that were not PPs, but rather, temporal NPs containing *about* used as a qualifier rather than a preposition, for example, *about a minute too late.*

One further study in the literature could be taken as a test of the Argument Preference Strategy, though it was not explicitly designed as

such. Spivey-Knowlton and Sedivy (1995) reported two experiments involving the attachment of PPs headed by *with,* one using "action verbs," which found a VP attachment preference modulated by definiteness, and one using "psychological predicates and verbs of perception," which found an NP attachment preference when the direct object was indefinite. While the authors acknowledged that these verb classes differ in that only the former systematically allows instrumental uses of *with,* they denied the relevance of argumenthood to this effect because they claim that instrumentals are not arguments. If, as we argue in Appendix A, instrumentals actually *do* have argument properties, then the contrast between verb classes would be explained by an argument preference, which would favor VP attachment for instrumental uses of *with* but not for modifier uses. But since all their items contained *with,* one cannot extrapolate from their findings to V-NP-PP structures in general.

The general picture is that all of the experiments reviewed here confounded various factors in assessing attachment preferences, and none of them constitute clear evidence for or against the Argument Preference Strategy. We therefore conducted new experiments to test the predictions of the Argument Preference Strategy against those of Minimal Attachment and those of theories that claim no general structure-based preference at all. Because Minimal Attachment and the Argument Preference Strategy agree on their predictions for comparing NP modifier and VP argument attachments, only the crucial NP argument versus VP modifier comparison, where predictions differ, was tested.

EXPERIMENT 1

Method

Participants. The participants were 33 native English speakers, students and other affiliates of MIT, who were paid for their participation.

Materials. We used materials similar to those of Clifton et al. (including some items adapted from theirs). Our 15 items, exemplified by (15), differed on only one word in the NP and VP

attachment conditions. Slashes demarcate regions, which were relevant only for the analysis.

(15) *Sample items*
　(a) *NP argument*
　　The company lawyers/considered employee demands/for a *raise*/but they/didn't act until a strike seemed imminent.
　(b) *VP modifier*
　　The company lawyers/considered employee demands/for a *month*/but they/didn't act until a strike seemed imminent.
　(c) *no PP*
　　The company lawyers/considered employee demands/but they/didn't act until a strike seemed imminent.

Five different prepositions were used. All items contained the same number of words up to the disambiguation point. They were tested using the five relevant argumenthood diagnostics discussed in Appendix A. Given the statement of the Argument Preference Strategy in (8), we counted an attachment as an argument if it clearly passed at least one diagnostic, though most examples passed several; modifier attachments never passed any of the argument tests. Mean length of the disambiguating noun in characters did not differ significantly (NP 6.2, VP 5.6, $t(14) = 1.17$, $p > .25$). Nouns in the VP condition were marginally more frequent than those in the NP condition (mean $\log_{10}$ frequencies in Francis & Kučera, 1982: NP 1.68, VP 2.15, $t(14) = -2.01$, $p = .06$), which works against our hypothesis that the NP condition should be processed faster.

We used a separate paper-and-pencil questionnaire in order to check for plausibility differences between the two critical conditions; 42 native English speakers who were not subjects in the on-line reading experiment participated. In order to preserve meaning and lexical content while removing temporary ambiguity, the critical sentences were passivized, so that the attachment of the PP was unambiguous, as exemplified by (16), corresponding to (15) above.

(16) (a) *NP argument*
　Employee demands for a raise were considered by the company lawyers.
　　(b) *VP modifier*
　Employee demands were considered for a month by the company lawyers.

NP argument PPs always immediately followed the head noun of the subject; VP modifier PPs appeared either immediately following the passive participle or at the end of the sentence, whichever sounded more natural. Subjects rated plausibility on a scale of 1 (natural) to 7 (unnatural). They were asked to judge the naturalness in the real world of the events described in the sentences, that is, how likely they were to occur. The 15 stimulus sentences were interspersed with 18 filler items, also all passive sentences, divided roughly equally between plausible and implausible according to our intuitions; each subject saw only one version of each experimental item. The difference between the NP and VP plausibility ratings was not significant, means 2.54 ($SD = 0.74$) for the NP argument versus 2.63 ($SD = 0.72$) for the VP modifier, $Fs < 1$. Thus, any reading time differences between our two critical conditions are unlikely to be due to a plausibility difference.

We included a third condition, exemplified by (15c), in an attempt to rule out another possible confound.[3] If VP modifiers are read more slowly than their NP argument counterparts, this could be because the argument analysis is initially preferred and must therefore be reanalyzed when the disambiguating noun is encountered in the VP condition. However, such a slowdown could also be due to an infelicity in the VP condition, namely, that it might sound odd to omit the argument of the object noun. For example, without a preceding context, it sounds strange to say *They discussed the likelihood yesterday,* because one has no idea what *likelihood* refers to in the absence of its complement. Similarly, because arguments in some sense encode an intrinsic part of the meaning of the head they attach to, sentences like (15b) and (15c) might be degraded due to the absence of any indication of what the employee

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[3] Thanks to Janet Fodor for suggesting this idea.

demands were for. Thus, the third condition omitted the PP entirely, so that its absence might be assessed independently of the ambiguity in the preposition.

The experiment included another set of items, from Rayner et al. (1983), in order to test whether their VP preference result would be replicated in our self-paced reading experiment. We used the shorter versions of their 12 sentence pairs.

Each subject read one version of each test sentence. The 15 + 12 test sentences were interspersed with 53 filler sentences of various types. These included items for other experiments with unrelated hypotheses. Each subject encountered the sentences in a different pseudorandom order.

Procedure. Subjects were timed in a word-by-word self-paced noncumulative moving-window reading task (Just, Carpenter, & Woolley, 1982) controlled by an IBM PS2 computer running Micro-Experimental Laboratory (MEL) software. Subjects pressed the space bar to reveal each subsequent word and cause all other words to revert to dashes. At the end of each sentence, a yes/no question appeared on the screen, which subjects answered by pressing one of two keyboard keys. Subjects were informed by a screen message when they answered incorrectly, in order to encourage them to keep paying attention to the content of the sentences. The experimental trials were preceded by two screens of instructions and eight practice trials. Most sentences spanned two lines on the screen (never more than two), with the disambiguating noun plus at least four words on the first line. The experiment took subjects approximately 20 min to complete.

Results

All subjects answered at least 80% of the questions in the experiment correctly. Trials on which the question was answered incorrectly were excluded from the analysis; this removed 3.6% of the sentences. The data we analyze are residual reading times per word (Ferreira & Clifton, 1986), derived by subtracting from raw reading times each subject's predicted time to read words of the same length, calculated by a linear regression equation across all sentences in the experiment. Residual reading times greater than 1000 ms were discarded, removing less than 1% of the remaining data. (Using tighter cutoffs, such as trimming to within 3 *SD* of the mean, separately for each word position in each condition across subjects, does not reveal any hint of effects different from those we report below.) For purposes of analysis only, items were divided into regions as follows: the initial NP (words 1–3, region 1), the verb and the object up to its head noun (words 4–6, region 2), the PP (words 7–9, region 3), the two words following the disambiguating noun (words 10–11, region 4), and the remainder of the sentence (region 5). All comparisons reported in this paper were computed by region unless otherwise noted. Mean residual reading times by region and standard errors are plotted in Fig. 3; corresponding raw reading times are given in Table 1. There were no significant reading time differences among any of the conditions in the first three regions (all Fs < 1). On the region following disambiguation, the NP argument version was read significantly faster than the VP modifier version, $F_1(1,32) = 5.55$, $MS_e = 2552$, $p < .05$, $F_2(1,14) = 4.96$, $MS_e = 1245$, $p < .05$. On that same region, the no PP condition was read more slowly than the NP argument condition, $F_1(1,32) = 4.79$, $MS_e = 2428$, $p < .05$, $F_2(1,14) = 8.97$, $MS_e = 736$, $p < .05$, and did not differ significantly from the VP modifier condition, Fs < 1. However, it was concluded that comparisons involving this condition were not meaningful—see the Discussion.

As for the items from Rayner et al., we omitted from the analysis 1 of the 12 that Taraban and McClelland (1988) had found in pretests was not given the intended interpretation by subjects. For the remaining 11 items, the VP-attached completions were read faster than the NP-attached completions on the three-word region following the disambiguating noun, significantly by subjects, −9.8 vs. 8.8 ms/word, $F_1(1,33) = 5.21$, $MS_e = 1139$, $p < .05$, $F_2(1,10) = 1.73$, $MS_e = 1286$, $p = .22$. (One more subject was included in this analysis as compared to the analysis of our items, in order to
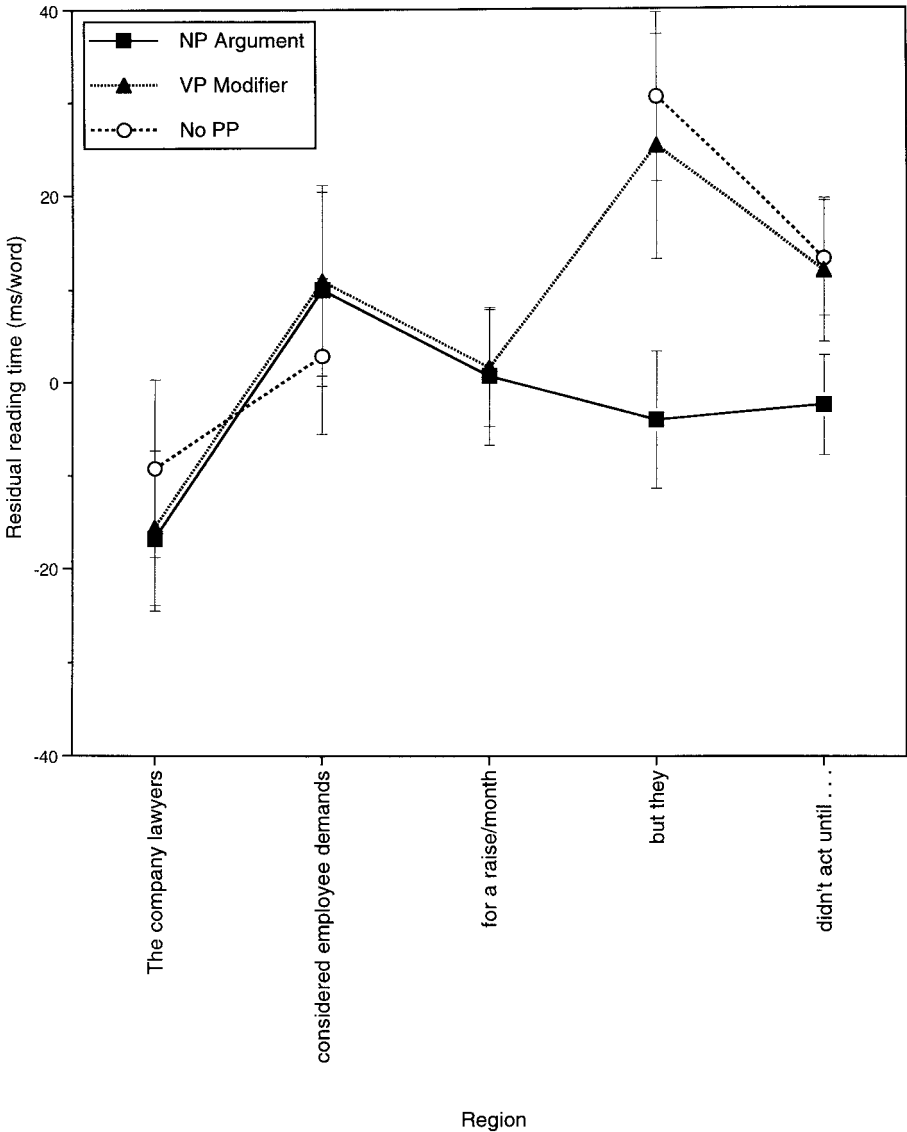
FIG. 3. Residual reading times for Experiment 1.

balance Rayner et al.'s two conditions.) With a tighter reading time cutoff at 3 *SD,* which removes 1.8% of the data, the items effect is marginally significant, $F_1(1,33) = 6.71$, $MS_e = 1435$, $p < .05$, $F_2(1,10) = 3.93$, $MS_e = 871$, $p = .08$. This result is consistent with Taraban and McClelland's (1988) replication of Rayner et al. Using the word-by-word self-paced reading paradigm they also found no disambiguation effect on the noun of the PP itself, and on

subsequent words the Minimal Attachment effect was significant by subjects but not by items. Similarly, when Britt et al. (1992) used this paradigm to present 16 items based on those of Rayner et al. in neutral contexts, their only significant effect was on a region which began after the disambiguating NP and comprised the whole remainder of the sentence. By way of comparison, in Rayner et al.'s original experiment, the significant advantage for VP attach-

TABLE 1

Mean Raw Reading Times per Word (in milliseconds)
for Experiment 1

	Sentence region				
Condition	1	2	3	4	5
Noun argument	351	392	345	342	355
Verb modifier	353	393	344	371	369
No PP	359	385	—	377	370

ment sentences was found over regions that began with the disambiguating word and included varying amounts of subsequent material.

Discussion

Our items showed a preference for NP argument over VP modifier attachment, as predicted by the Argument Preference Strategy, and showed no evidence for an initial Minimal Attachment effect. Our findings thus are consonant with the later argumenthood effect of Clifton et al. (1991), but not with the earlier VP preference they found. Because Rayner et al.'s items did show a Minimal Attachment pattern, its absence in our items cannot be an artifact of experimental conditions. However, two potential confounds remain, which are addressed in Experiment 2.

First, the reading time difference between NP and VP completions might reflect inherent complexity differences between NP arguments and VP modifiers, independent of ambiguity. The usual method of controlling for this possibility is not available to us: we would like to compare each resolution of the ambiguity to a corresponding unambiguous control sentence, but there is no way in English to disambiguate toward the NP argument reading without substantially altering the syntax of the sentence.

Second, an anomaly effect due to the absence of the argument of the direct object has not been ruled out. As can be seen in Fig. 3, the No PP condition appears to have patterned more like the VP condition, which would be consistent with an anomaly-based explanation for the NP/VP contrast. However, this is not a straightforward comparison, because the words being

compared (e.g., *but they* in (15)) occurred earlier in the no PP condition than in the other two conditions, immediately following the direct object noun. Thus, various confounds could be at play, including differential spillover from the preceding word, a possible surprise effect due to the relative shortness of the VP in this condition, etc. For these reasons, we do not wish to draw any conclusions based on the no PP condition; the anomaly confound hypothesis (as well as the complexity difference hypothesis) was tested in a different way in Experiment 2.

EXPERIMENT 2

Method

Participants. The participants were 82 native English speakers, students and other affiliates of MIT, who were paid for their participation. None of them had participated in Experiment 1.

Materials. Fifteen NP and VP attachment sentence pairs were identical to those in Experiment 1. However, the third condition now contained a PP headed by a different preposition, as exemplified in (17c). Again, slashes demarcate regions, which were relevant only for the analysis.

(17) *Sample items*
   (a) *NP argument*
      The company lawyers/considered employee demands/*for a raise*/but they/didn't act until a strike seemed imminent.
   (b) *VP modifier*
      The company lawyers/considered employee demands/*for a month*/but they/didn't act until a strike seemed imminent.
   (c) *unambiguous PP*
      The company lawyers/considered employee demands/*after a month*/but they/didn't act until a strike seemed imminent.

This new preposition unambiguously could not be construed as introducing an argument of the direct object noun, and the PP was most plausibly a VP modifier. Thus, it allowed us to test for effects resulting from the absence of the

noun's argument and from the inherent complexity of the VP modifier structure, independent of possible reanalysis effects. Whenever it was feasible, the noun in this PP was identical to that in the VP condition (as in (17)), but when this could not be felicitously achieved, a different noun was substituted. (See Appendix B for a complete list of items.) Overall, the nouns in the unambiguous PP condition did not differ significantly in length or frequency from those in either of the other conditions. As for the prepositions, those in the unambiguous condition were marginally longer than those in the other conditions (mean 3.80 versus 2.87 characters, $p = .068$), and significantly less frequent ($\log_{10}$ frequency unambiguous $= 3.28$, ambiguous $= 3.85$, $t(14) = 4.07$, $p < 0.005$). These differences could, if anything, lead the unambiguous PP condition to be read more slowly than either of the other two conditions, which would work against our hypothesis, as discussed below.

In the interests of maximizing experimental resources, two versions of the experiment were run on different subjects, in which our 15 experimental items and filler sentences were combined with items for two other sets of experiments with unrelated hypotheses. We treat these as two subject groups in the analysis, containing 50 and 32 subjects, respectively. The first group read a total of 103 sentences, including 48 for other experiments, and the second group read 80 sentences, including 32 for other experiments.

Procedure. The experimental procedure was identical to that of Experiment 1, except that it was run on a Macintosh Centris computer using custom software.

Results

Six subjects were omitted from the analysis: 4 had fewer than 80% correct answers on the relevant questions[4]; 1 noticed an ambiguity in the practice items similar to the one tested in the

[4] For two of these subjects, question-answering accuracy was computed over a subset of 55 of the sentences in the experiment: 15 test items and 40 fillers. We excluded items for other experiments because they were substantially more difficult.

experimental items and commented on it; and 1 feel asleep during the experiment. For the remaining 76 subjects, residual reading times were calculated and data were filtered as in Experiment 1: 6.6% of the sentences were removed due to incorrect question answering, and remaining residual reading times greater than 1000 ms were removed (less than 1% of the data). (As in Experiment 1, using tighter cutoffs does not reveal any hint of effects different from those we report below.) As there were no significant effects of subject group, and no interactions between this and any other factors, results are collapsed across groups.

Residual reading times and standard errors for all three conditions are displayed in Fig. 4; corresponding raw reading times can be found in Table 2. There were no significant reading time differences among any of the conditions preceding the disambiguating noun (all $ps \geq .20$). On the two-word post-disambiguation region, the NP condition was read faster than the VP condition, significantly by subjects, $F_1(1,74) = 8.67$, $MS_e = 3734$, $p < .005$, and marginally by items, $F_2(1,14) = 4.04$, $MS_e = 2260$, $p = 0.06$. If this region is expanded to three words including the disambiguating noun, the effect is significant by both subjects and items, $F_1(1,74) = 8.29$, $MS_e = 2357$, $p < .005$, $F_2(1,14) = 4.83$, $MS_e = 1247$, $p < .05$. Regarding the unambiguous PP condition, it did not differ significantly from the NP condition in any region ($ps > 0.30$). However, it was read faster than the VP condition on the critical fourth region, significantly by subjects, $F_1(1,74) = 8.88$, $MS_e = 3697$, $p < .005$, and marginally by items, $F_2(1,14) = 4.20$, $MS_e = 2134$, $p = 0.06$.

Discussion

Experiment 2 replicates our finding from Experiment 1 that NP argument sentences were read more quickly than VP modifier sentences. Again, there was no evidence of an initial VP preference. In addition, the results for the unambiguous condition allow us to rule out two alternative explanations for this contrast. Because the unambiguous condition was read faster than the ambiguous VP condition and not slower than the NP condition, the slowdown in
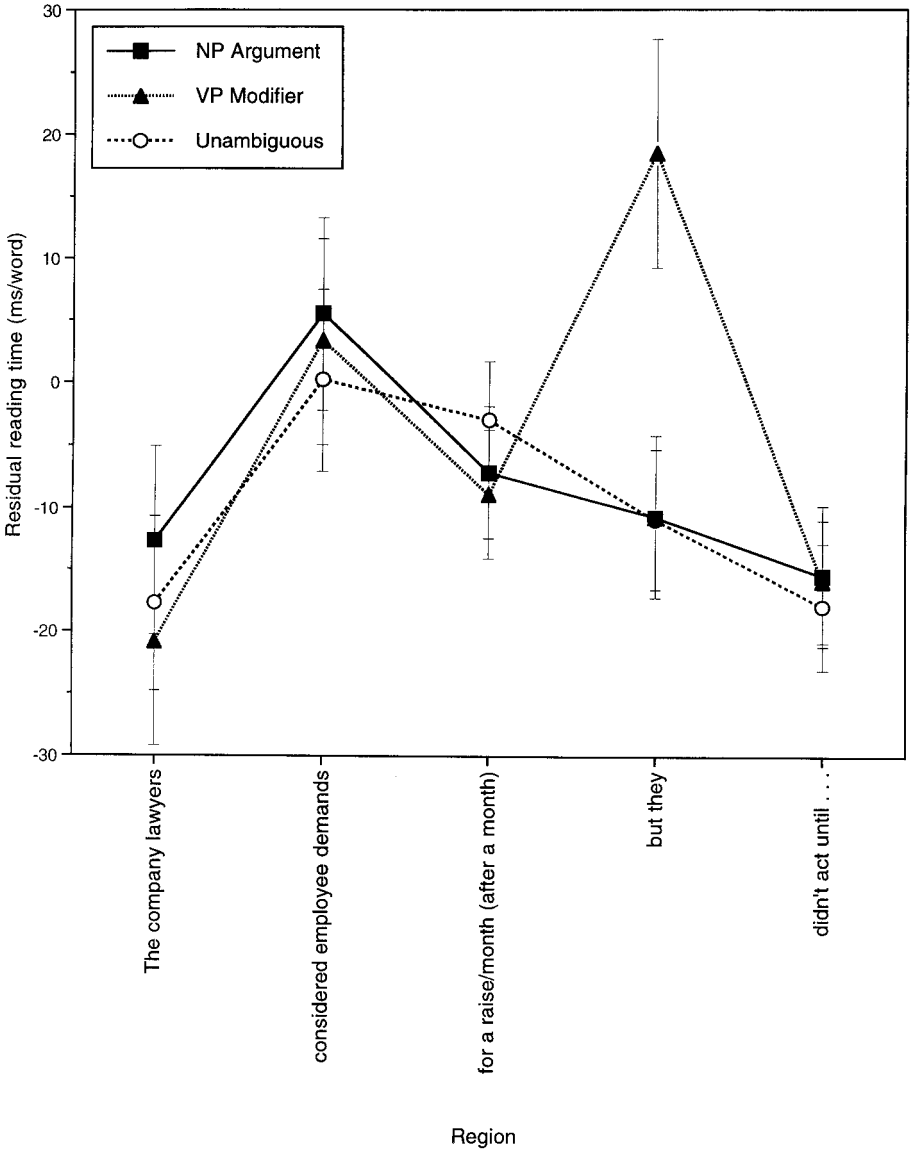
FIG. 4. Residual reading times for Experiment 2.

the ambiguous VP condition cannot be attributed merely to the absence of an "expected" argument of that noun, nor to the inherent complexity of a VP modifying the PP structure. Any such effects would have manifested themselves in a slowdown in the unambiguous condition beginning in the PP region, where the absence of the argument PP became apparent. Rather, the slowdown in the ambiguous VP condition is a garden path/reanalysis effect, indicative that

the ambiguous preposition was initially taken as introducing an argument to that noun.

GENERAL DISCUSSION

We have shown that when several other factors are controlled for, the difference between argument and modifier attachments affects the initial analysis constructed by the parser for V-NP-PP ambiguities. Thus, in contrast to authors cited earlier, we find that an argument

TABLE 2

Mean Raw Reading Times per Word (in milliseconds)
for Experiment 2

Condition	Sentence region				
	1	2	3	4	5
Noun argument	362	393	346	344	347
Verb modifier	354	390	343	372	347
Unambiguous PP	357	388	354	345	344

preference is one factor in the initial resolution of this ambiguity and not just a later effect, as Clifton et al. (1991) found. Minimal Attachment as formulated by Frazier and colleagues cannot therefore be the initial determinant of parsing decisions, although, as noted earlier, a strategy of minimizing tree nodes could be, if certain syntactic assumptions were made. In the rest of this section, we consider how the argument preference hypothesis relates to other contending accounts, such as statistical properties of lexical items or more general structural principles.

First, let us consider an alternative structural account, namely, that the preference for NP attachment in our experiments might be due to a Recency, Right Association, or Late Closure strategy (cf. Kimball, 1973; Frazier, 1978; Frazier & Fodor, 1978; Gibson, 1991, 1998; Stevenson, 1994). Because the noun represents a more recent potential attachment site than the verb in a V-NP-PP sequence, a recency-based preference by itself might lead one to expect NP attachment to be preferred. However, recall that with different sets of items, we and many other researchers have found a VP attachment preference for this ambiguity. The Argument Preference Strategy explains both sets of results, given our observation that the preferred VP attachments in previous work were mostly argument attachments (e.g., instrumental *with* phrases). If our NP preference were instead treated as a pure recency effect, some additional competing factor would have to be posited to handle the examples in which VP attachment is preferred, and one would have to explain why the relative strengths of recency and this com-

peting factor seem to be sensitive to argumenthood contrasts. Thus, on grounds of parsimony it is preferable to posit a single general principle, the Argument Preference Strategy, rather than to stipulate a property of a constraint that is relevant only in one particular configuration. (However, see Phillips (1996) for an attempt to derive some argument preferences from a purely structural principle related to Late Closure.)

Let us now consider a different kind of potential alternative to the Argument Preference Strategy, parsing theories based on lexical frequencies such as those of Trueswell and Tanenhaus (1994) or MacDonald, Pearlmutter, and Seidenberg (1994). (Note that, like Speer and Clifton (in press), we have found evidence that plausibility differences are not responsible for the observed disambiguation preference.) MacDonald et al. claim that apparent argumenthood effects may be reducible to relative co-occurrence frequencies:

> [The] frequency coding of preferences for different prepositional phrases (PPs), particularly in a distributed representation described earlier, largely eliminates the argument–adjunct distinction that is common to many discussions of PP attachment ambiguities. . .In our view, an argument is a PP that is strongly (frequently) linked to a word (e.g., the location role for *put*) and an adjunct is one that is weakly (infrequently) linked (e.g., the manner role for *put*). It is possible that the frequency biases that we have described derive from deeper relationships between the semantics of the verbs, nouns, and thematic roles. . . (MacDonald et al., 1994, p. 694).

We take up the discussion on three fronts. First, could frequency biases alone account for the results we have obtained? Second, is argumenthood reducible to relative frequency? Third, if it is not, what further experiments could tease apart the frequency bias and argument preference hypotheses?

In response to the first question, we conducted a posthoc assessment of frequency biases in our 15 items to see whether the particular prepositions more frequently attach to NP rather than VP under certain conditions. This required a specific hypothesis as to the grain size of frequencies that the parser might be sensitive to when resolving a V-NP-PP attach-

ment (cf. Mitchell, 1994; Gibson, Schütze, & Salomon, 1996; MacDonald, 1997). At least the following possibilities could be considered, listed in order from fine to coarse:

For a given preposition, e.g., *for,*

1. Count only occurrences that involve both the particular noun and the particular verb in question, in the relevant structural relationship, i.e.,

[$_{VP}$ *consider* [$_{NP}$. . .*demand*] *for*. . .] and [$_{VP}$ *consider* [$_{NP}$. . .*demand for*. . .]. . .].

2. Count only occurrences in which the preposition attaches to the particular noun as first object of a verb or to the particular verb following a first object, i.e.,

[$_{VP}$ V [$_{NP}$. . .*demand for*. . .]] and [$_{VP}$ *consider* NP *for* . . .].

3. Count only occurrences in which the preposition attaches to the particular noun or the particular verb in question, i.e.,

[$_{NP}$. . .*demand*. . .*for*. . .] and [$_{VP}$. . .*consider* . . .*for*. . .].

4. Count only occurrences in which the preposition follows the first object of a verb, i.e.,

[$_{VP}$ V [$_{NP}$. . .N [$_{PP}$ *for*. . .]. . .]. . .] and [$_{VP}$ V [$_{NP}$. . .N] [$_{PP}$ *for*. . .]. . .].

5. Count all occurrences in which the preposition attaches to an NP or to a VP, i.e.,

[$_{NP}$. . . [$_{PP}$ *for*. . .]. . .] and [$_{VP}$. . . [$_{PP}$ *for*. . .]. . .].

Of these possible grain sizes, 4 and 5 are not in the lexicalist spirit argued for by MacDonald, Tanenhaus, and their colleagues, because they count across whole classes of structures rather than ones headed by particular words. Grain sizes 1 and 2 occur too sparsely for meaningful frequencies to be computed. We therefore tested grain size 3, based on an automatic search of the UPenn Treebank parsed corpora (Marcus, Santorini, & Marcinkiewicz, 1993), which yielded proportions such as the following, relevant to example (17) above:

((*demand*. . .*for*)/*demand*)   = 0.390
((*consider*. . .*for*)/*consider*) = 0.015.

Across all 15 items, we found mean proportions for $N + prep$ of 0.165 and for $V + prep$ of 0.040; the $N + prep$ combinations were propor-

tionally significantly more frequent on average, $t(14) = 2.87$, $p < .05$, based on the comparison of arcsine proportions. Breaking this down, there were 11 items where the NP argument was more frequent, 3 items where the VP modifier was more frequent, and 1 item where both had zero frequency in the corpora. Thus, it is possible that our specific experimental finding could be accounted for by a frequency-based algorithm. However, it is also worth noting that, on an item-by-item basis, the proportion differences between $N + prep$ and $V + prep$ pairs showed no hint of a linear correlation with the reading time differences in either Experiment 1 or Experiment 2 ($p > .5$ for each correlation).

Turning now to the second question raised above, it is our contention that if relative frequency were all there was to argumenthood, the syntactic differences between arguments and modifiers summarized in Appendix A would be left unexplained. While one might be able to imagine intuitively why more frequently co-occurring pairs of head and PP might conform to the generalizations about ordering (see (20)–(23) in Appendix A), separation ((35)–(39)), and pro-form replacement ((30)–(32)), it is unclear why the iterativity ((28)–(29)) and *wh* extraction ((40)–(50)) tests should work as they do, instead of in the opposite way. Furthermore, no frequency-based account of any of the argumenthood diagnostics has actually been proposed. Thus, we take argumenthood to be fundamentally a syntactico-semantic property of linguistic expressions. While argumenthood and frequency surely correlate to a high degree, we suggest that frequency differences derive from argument–structure differences, rather than vice versa. (MacDonald et al. also acknowledge such a possibility.)

Given this claim about the grammar, we can refine the third question: Is the parser actually sensitive to grammatical argumenthood or to simple frequencies? These two options are distinguishable in principle by using examples that contrapose a low-frequency argument and a high-frequency modifier. In such cases, the two hypotheses make opposite predictions about processing. Our initial attempts to carry out this test indicate that it will be difficult in practice, how-

ever. The biggest obstacle is that the available parsed English corpora, consisting of about one million words each, are insufficiently large to provide reasonable estimates of the actual co-occurrence frequencies required, because these involve the presence of two particular lexical items. Our scrutiny of co-occurrence frequencies computed from this corpus shows them to be extremely sensitive to the particular materials sampled from the corpus and intuitively unrepresentative of everyday English. We therefore attempted to derive frequency estimates from a larger but unparsed corpus, the "Tipster" 1989 Associated Press Newswire corpus (compiled by the Linguistic Data Consortium at the University of Pennsylvania), which consists of approximately 41 million words. The problem here is that automatic searching cannot do much more than find sentences in which the 2 specified words occurred in the requisite order. To determine whether they are in the relevant syntactic relationship, one must filter all the sentences by hand, an arduous task. It is therefore impractical to attempt to extract all V + P and N + P collocation frequencies from large unparsed corpora. Rather, some way of narrowing the search to plausible candidate combinations was required. We used the relative frequencies from the Penn Treebank, plus our intuitions, as guides to promising choices of words. The results of such preliminary attempts were proportions like the following: ((*study*. . .*for*)/*study*) = 0.054 and ((*possibility*. . .*for*)/*possibility*) = 0.018. (While in its intransitive use, *study for NP* probably involves a PP argument, the sentences we test will necessarily have a direct object, so the relevant fact is that in *study NP for NP*, the PP is not an argument of the verb.) Of course, in order for such pairs to be useful in constructing stimuli for testing the competing hypotheses, it must additionally be possible to construct a plausible sentence containing the verb with the noun as its direct object, for example, (18).

(18) (a) The UN envoy studied the possibilities for a truce before he left on the peace mission.

(b) The UN envoy studied the possibilities for a while before he left on the peace mission.

It remains to be seen whether it is practical to construct a full set of experimental stimuli in this manner.

Frequency-based versus semantically based approaches differ not only in their claims about how the parser works, but also in how they relate parsing to language production. A hypothesis such as the Argument Preference Strategy provides the basis for an explanation of both human parsing behavior and the observed co-occurrence patterns, whereas the frequency-based approach does not offer an account of the co-occurrence patterns, treating them as arbitrary (Gibson, Schütze, & Salomon, 1996; Stevenson & Merlo, 1997; among others). Given the semantic characterization of arguments versus modifiers, it seems reasonable to view the distinction roughly as contrasting an intrinsic component of some event or state of affairs with an incidental property of that event or state. To the extent that co-occurrence frequencies correlate with argumenthood, a plausible explanation would be that we are generally more likely to talk about the intrinsic or identifying properties of events than about accidental or nonessential ones.

In conclusion, we have shown that models of disambiguation, at least for the V-NP-PP ambiguity, must take into account some measure of the syntactico-semantic cohesion among the particular lexical heads that occur in the sentence—either argumenthood or something closely correlated therewith. The challenge for future work in this area is to develop an explicit theory of how all the relevant factors, including argument status, combine to determine initial preferences in ambiguity resolution.

APPENDIX A: DIAGNOSTICS FOR PP ARGUMENTS

In this appendix we summarize six syntactic diagnostics for argumenthood of prepositional phrases associated with nouns and verbs. Because our experiments were conducted only in English, we discuss only diagnostics that apply in English; many of them are not applicable in other languages. (Thus, when testing for argumenthood effects in other languages, the relevant syntax literature for those languages must be consulted.) In all cases there is more to be said about the applicability of the diagnostics summarized here than space permits, so they cannot be safely used without consulting additional sources. Some further details can be found in Schütze, 1995; see Miller,

1997, for some related discussion. The diagnostics also do not all draw the same dividing line between arguments and modifiers, and the underlying syntactic mechanisms are in many cases not fully understood; we return to these matters in the final section.

Optionality

The most common rule of thumb for identifying arguments is that arguments to a particular lexical head can be obligatory, whereas modifiers are (almost) always optional, but the converse is not true: there are optional arguments (Jackendoff, 1977). This test tells us that the PP in (19a) is functioning as an argument of V, while the one in (20a) could be a modifier:

(19) (a) John put the book in the room.
     (b) *John put the book.
(20) (a) John saw the book in the room.
     (b) John saw the book.

This test is listed here for completeness; it is not helpful in the present context, because if the direct object noun in a V-NP-PP sentence took an obligatory PP argument, there would be no ambiguity of attachment of the PP—it would have to attach to the NP. *Verbs that take obligatory PP arguments have rarely been used in the experimental literature on this ambiguity (but see Ferreira & Clifton, 1986 and Britt, 1994), presumably because this would create a confounding asymmetry between NP and VP attachment—*nouns* in most environments do not take obligatory arguments. Our own stimuli therefore used only optional arguments.

Ordering

Arguments generally must precede modifiers (Jackendoff, 1977; Pollard & Sag, 1987), while modifiers may follow other modifiers and arguments may follow other arguments, as the following contrasts demonstrate. (Asterisks indicate only ungrammaticality of the relevant reading of a string; for example, (23b) is grammatical if a specific ring over Buffalo is under discussion.)

(21) (a) a member of Parliament with gray hair
     (b) *a member with gray hair of Parliament
(22) (a) a man from Paris with gray hair
     (b) a man with gray hair from Paris
(23) (a) While we were flying home, I gave the ring to my girlfriend over Buffalo.
     (b) *While we were flying home, I gave the ring over Buffalo to my girlfriend.
(24) (a) John saw the mouse in the kitchen on Sunday.
     (b) John saw the mouse on Sunday in the kitchen.

Pollard and Sag (1987) note that constituents in VP can often be reordered so that they superficially violate this generalization, but that such reordering is usually correlated with focus on the clause-final constituent. For example, (25) focuses the indirect object, which concomitantly requires a certain amount of stress.

(25) Lou handed a book last Sunday to the kids.

Hence, if in a given sentence it is impossible to put focal stress on some *nonfinal* constituent, the word order is not a base order, because only derived word orders force stress to be on the final phrase. The following examples make this clearer (italics are used to indicate focal stress).

(26) *Lou handed a book on *Sunday* to the kids.
(27) (a) Chris read a book on *Sunday* after lunch.
     (b) Chris read a book after *lunch* on Sunday.
(28) (a) They complained to the *landlord* about the tenants.
     (b) They complained about the *tenants* to the landlord.

Thus, (26) confirms that *to the kids* is an argument—the impossibility of nonfinal stress indicates that the PP cannot be base-generated after a temporal modifier PP. Because its base position is obligatorily before a modifier, it must be an argument. By comparison, the alternative orders in (27) and (28) show that neither PP obligatorily precedes the other in base word order. Therefore, the two PPs in each pair are shown to have the same status. Once the status of one PP is independently established, this test can be used to diagnose the status of another; in this case, (27) involves two modifiers and (28) involves two arguments.

Iterativity

Modifier phrases can usually iterate while argument phrases cannot (cf. Fillmore, 1968; Bresnan, 1982; Pollard & Sag, 1987):

(29) (a) *Chris rented the gazebo to yuppies, to libertarians.
     (b) Kim met Sandy in Baltimore in the hotel lobby in a corner.
(30) (a) *I met a student of biology, of molecular genetics.
     (b) I met a student with blue eyes with a wonderful smile.

Care must be taken in applying this test, however: if the iterated phrases are semantically incompatible with each other then this can make the example seem bad for the wrong reason. For instance, the badness of *I met a student with blue eyes with green eyes* is uninformative. In general, good cases seem to require modifiers that refer to slightly different properties or else to a different level of detail (Brunson, 1992), as with the increasingly specific locations in (29b).

Pro-form Replacement

If a PP is *obligatorily* deleted when the noun or verb head with which it is associated is replaced by a pro-form (a form that can stand in for an expression that appeared earlier, such as *one* in (31) or *do so* in (32)), that PP is an argument of the replaced head; if not, it is a modifier. [For NP, see Lakoff, 1970, crediting L. Baker; for VP, see Ross, 1973; Lakoff & Ross, 1976 (1966); and Klima, 1962; for analysis, see Jackendoff, 1977.] This is shown for nouns in (31), and for verbs with *do so* in (32) and with pseudoclefts in (33).

(31) (a) *The President proposed the solution to the foreign crisis, not the one to the domestic crisis.

   (b) I know the woman from Peel, not the one from London.

(32) (a) *John put a book on the table, and Sue did so on the shelf.

   (b) John filled out the form in pen, and Mary did so in pencil.

(33) (a) *What the authorities did on Mary was blame the arson.

   (b) What Chris did in the backyard was cook dinner.

In (31a), *do so* has been substituted just for *solution*, leaving behind the following PP headed by *to;* the ungrammaticality of the sentence indicates that the PP cannot be left in but must be deleted, so it is an argument. By contrast, in (31b) a PP headed by *from* appears with *one*, just as it did with *woman*, so the grammaticality of the sentence indicates that this PP is not an argument. The facts in (32) show that the same contrast holds for PPs that follow a direct object NP. In (33a) we have tried to combine the PP *on Mary* with the pro-form *did*, and this has yielded ungrammaticality, which means that this PP must be deleted when the pro-form is used, so the PP is an argument. On the other hand, in (33a) the PP is combined with the pro-form *did*, and since the sentence is grammatical, that PP is not obligatorily deleted when the pro-form is used, so the PP is not an argument.

The noun test is inapplicable if the intended antecedent noun is not countable. Thus, the badness of (34) does not bear on the argumenthood of the PPs, because *water* and *destruction* cannot be antecedents for a *one* anaphor.

(34) *The water in the lake is cleaner than the one in the river.

Similarly, the verb replaced by *do so* cannot be stative, hence the badness of (35).

(35) *Bill knew about our affair, and Harry did so, too.

Separation from the Head

If a PP can be separated from its associated noun by a copula or a relative clause construction, it is a modifier; if it cannot, it is an argument (cf. Jackendoff, 1977, p. 60; Grimshaw, 1990).

(36) (a) the man (who) is from Paris

   (b) the book (that) was by/about Chomsky

(37) (a) *a student (who) was of physics

   (b) *the solution (that) was to the problem

Certain uses of *with* cannot be paraphrased by *be with* for independent reasons (cf. Freeze, 1992, inter alia), but do allow a paraphrase with *have:*

(38) (a) *a man (who) was with blue eyes

   (b) a man (who) has blue eyes

For VP elements, if a preposed PP can be followed by a question it is a modifier, if it cannot it is an argument (Reinhart, 1983; Emonds, 1976):

(39) (a) On Tuesday, who drove to the store?

   (b) At the concert, did you fall asleep?

(40) (a) *On the shelf, who put the book?

   (b) *To Mary, did John give a ring?

Wh-Extraction

Wh-extraction is a syntactic phenomenon in which a phrase consisting of or containing a question word (e.g., *who, what, which,* etc., most of which begin with the letters *wh* in English) is moved to the beginning of a clause. The position from which the *wh*-phrase has moved may be indicated with a trace, notated as *t.* As (41) versus (42) shows, *wh*-extraction of or from a PP that is inside a direct object is generally possible, but this is not so for modifiers (Radford, 1988; cf. Ross, 1967; Jackendoff, 1977; Bach & Horn, 1976; Chomsky, 1977; Koster, 1978; Culicover & Wilkins, 1984; Diesing, 1992):

(41) (a) *Which shelf did you read [a book on *t*]?

   (b) *With what kind of sleeves did you buy [many sweaters *t*]?

(42) (a) Which problem did the President suggest a solution to?

   (b) Of which city did you witness the destruction?

There is an orthogonal restriction, traditionally stated as a ban on extraction from "specific" NPs, which Diesing (1992) suggests is actually a ban on extraction from presuppositional NPs, NPs that presuppose the existence of their referent, rather than asserting it (see Diesing, 1992, for extensive discussion). She argues that the complements of experiencer verbs (*love, like, appreciate, hate*) and destruction verbs (*destroy, burn, ban, tear up*) are presuppositional. As a consequence, extraction is generally impossible from those complements, but it is possible from complements to verbs of creation (*write, paint, draw*) or using (*read, play, publish, buy, see*). Thus, the latter are the best ones for applying this test.

Further caution is advised because the extraction test can yield grammatical results for the wrong reason. Bach and Horn (1976) note that the following types of sentences do not unambiguously involve extraction from an NP:

(43) (a) Which country did you explore caves in?

   (b) Who did you take a picture of?

The reason is that *explore* licenses a PP, independent of *caves*, as in *John explored them in Mexico;* similarly, we can say *John took it of Mary* (e.g., in response to *Where did that picture come from?*). Thus, (43) tells us nothing about the possibility of extracting from NPs. The solution is to apply the test using a main verb that is shown independently not to license the relevant PP. Thus, (44c) is evidence for argumenthood, but (45c) is evidence against it.

(44) (a) I saw a picture of Mary.

   (b) *I saw it of Mary.

   (c) Who did you see a picture of?

(45) (a) I know men in overcoats.

   (b) *I know them in overcoats.

   (c) *Which overcoats do you know men in?

At the VP level, the analogous pattern emerges in extraction from "weak islands," syntactic constituents of several types (exemplified below) that prohibit certain kinds of *wh*-extraction (Rizzi, 1990; Cinque, 1990; Hukari & Levine, 1995; Szabolcsi & Zwarts, 1993). In these environments, extraction of or from arguments is relatively good, extraction of or from modifiers is much worse.

Wh-islands.

(46) ?To which friend do you wonder [whether John gave the book *t*]?

(47) *On which day last week do you wonder [whether John bought the book *t*]?

Adversative/factive islands.

(48) To which friend do you deny [that Bob gave his ring *t*]?

(49) *At what time do you regret [that Bob walked to the market *t*]?

Extraposition islands.

(50) Which critic is it time [for Mary to describe her film to *t*]?

(51) *What country is it a scandal [that the Senator got divorced in *t*]?

Baker (1988) points out some apparent exceptions to this pattern, which might be explained in the framework of Pesetsky (1995); see Schütze, 1995, for discussion.

Instrumentals

The status of instrumental *with* phrases as arguments or modifiers is of particular interest because some previous studies of the V-NP-PP ambiguity have restricted themselves largely (Rayner et al., 1983) or entirely (Altmann & Steedman, 1988; Clifton & Ferreira, 1989; Spivey-Knowlton & Sedivy, 1995) to the preposition *with*. See Nilsen, 1973; Gruber, 1965; Marantz, 1984; Brunson, 1992; and Larson, 1988, for review of the primary literature concerning instrumentals; see Sedivy & Spivey-Knowlton, 1994; Spivey-Knowlton & Sedivy, 1995; and Schütze, 1995, for discussion of other tests.

Instrumentals pattern with arguments on three of the syntactic tests. As shown in (52), they cannot be iterated (as observed by Lakoff (1968); cf. Bresnan, 1982). Like other arguments, they cannot be followed by a question (53), and they can be extracted from weak islands (54) (cf. Baker, 1988, p. 243):

(52) *John cut the meat with a knife with the sharp end.

(53) *With the knife, who sliced the salami?

(54) With which key do you deny that the butler could have opened the door?

See Schütze, 1995 for additional semantic evidence that instrumentals have argument properties; Konieczny (1996) made this claim based on tests summarized by Pollard and Sag (1987). Given the conclusion that *with* instrumentals are arguments, we did not use *with* in any of our experimental items, because our aim was to test VP attachments that could only be modifiers.

Interpreting the Diagnostics

It is worth asking what the relationship is between the syntactic contrasts illustrated here and the nature of argumenthood. One traditional view has been that arguments and modifiers appear in different structural positions and that their contrasting syntactic behavior follows from the difference in position. Traditionally, arguments were taken to be sisters to the syntactic head that assigned their semantic role, while modifiers were sisters to an X-bar level category, with perhaps the further restriction that they must also be daughters of a (recursive) X-bar level category. Leaving aside the question of how this distinction can be replicated in current syntactic theory, we can ask whether the purported argumenthood diagnostics appear to reflect this structural dichotomy uniformly. The answer seems to be No (Schütze, 1995). Furthermore, intuitions on these tests often seem to lie in the range between complete grammaticality and strong ungrammaticality. Precisely what this means is a deep and unresolved issue for syntactic theory, but it is tangential to our hypothesis about parsing. Among the possible answers are the following. (Thanks to an anonymous reviewer for laying out some of these.) First, perhaps arguments and modifiers do not always appear in different syntactic environments, as suggested, for example, by Pesetsky (1995). Second, it is possible that grammaticality judgments are reflecting factors other than sentence structure and semantic argumenthood—see Schütze (1996) and work cited there. A third possibility is that some of the diagnostics may reflect an underlying continuous semantic notion of argumenthood that is only imperfectly replicated in a positional dichotomy. Fourth, it is possible that there is an underlying dichotomy at the level of semantic composition: the rule for combining a head with an argument to form a predicate must be different from the rule for predicating a modifier of an already-formed predicate. However, there may well be many cases where the resulting meaning is virtually indistinguishable. This is particularly likely in the construction under discussion here, because prepositions can apparently do double duty as either semantically contentful heads in their own right or relatively meaningless words, similar to case markers, whose presence is simply dictated by the choice of verb. If the meaning that a verb assigns to its argument happens to be close to the meaning that the preposition itself can assign when used to form a modifier, intuitions of marginal acceptability would not be surprising.

What is relevant to the parsing questions is that the available intuitions about sentences, be they "direct" semantic intuitions of the sort described in connection with (3)–(6) or intuitions about the well-formedness of various syntactic manipulations, are not binary. As a result, for purposes of presentation we assume that argumenthood is not an all-or-nothing phenomenon, but that it occurs in degrees. That is why in formulating the Argument Preference Strategy (8) we proposed that the parser maximizes the *extent* of argument relations. This means that an attachment that passes only two or three argument diagnostics, or one that yields marginal results on all of them, is still hypothesized to be preferred by the parser over one that shows no evidence of an argument relation.

APPENDIX B: SELF-PACED READING ITEMS

In each item, the two nouns separated by a slash are the NP argument and VP modifier versions, in that order. The control condition in Experiment 1 omitted the italicized PP entirely. The control condition in Experiment 2 replaced the italicized PP with the one given in parentheses after each sentence.

1. The financial administrator announced many cuts *in the staff/meeting* although he knew it would upset numerous people. (at the meeting)

2. The older campers questioned John's authority *over the group/summer* but they came to respect him after the big campfire. (during the summer)

3. The community leader withheld his support *for the candidate/moment* while he waited to hear what the incumbent would say. (during the debate)

4. The confused suspect admitted his involvement *in the robbery/morning* but later he claimed he was coerced. (at the station)

5. The revised policy increased people's alienation *from the system/outset* but the senate failed to recognize it for many months. (across the country)

6. The environmental agency allowed some exemptions *from the law/start* but there were still objections from certain industries. (at the hearing)

7. The science teacher encouraged much excitement *over the project/week* by bringing in new experiments for the children to try every day. (during the week)

8. The keen shopper expressed his interest *in a wallet/hurry* just before the store was about to close. (after a moment)

9. The police detective conducted a search *for a weapon/day* but he never looked in the suspect's car. (at a warehouse)

10. The experienced general concealed his surprise *at the decision/time* but was not sure what to do next. (for the moment)

11. The comedian's friends showed their amusement *at the story/party* because they were thoroughly enjoying themselves. (during the party)

12. The company lawyers considered employee demands *for a raise/month* but they didn't act until a strike seemed imminent. (after a month)

13. The board members discussed Mary's inclusion *in the process/afternoon* after they had met with the president over lunch. (at the briefing)

14. The boisterous fans gained some confidence *in the coach/end* after their team came back to force the game into overtime. (by the end)

15. The new conductor noticed Arthur's absence *from the rehearsal/beginning* but he didn't comment on it until later. (at the rehearsal)

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