

Distinguishing Generation and Selection of Modifier Attachments: Implications for Lexicalized Parsing

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We investigated the lexicalization of syntactic knowledge in two reading experiments, one using a moving window paradigm and one measuring eye movements. Our study was motivated by Spivey-Knowlton and Sedivy's (1995) finding that verb class, and by implication frequency information, determined how easily a prepositional phrase (PP) was attached to a verb phrase (VP) or to a direct object noun phrase (NP). Because they found longer reading times for NP-attached PPs than for VP-attached PPs following action verbs, and the reverse pattern for psych/perception verbs, their data seem to demonstrate that adjunct slots and their frequencies are encoded in the lexical entry of the verb. Such detail is consistent with a highly lexicalized parser, in which both argument and adjunct slots are represented in the lexical entry of each phrasal head. However, we came to different conclusions after using stimuli that were very similar to those used in Spivey-Knowlton and Sedivy, but that compared temporarily ambiguous sentences with unambiguous versions. We essentially replicated the Spivey-Knowlton and Sedivy results using temporarily ambiguous sentences, though the results were not robust in the item analyses. In contrast, with unambiguous versions, we found lexical frequency effects for argument PPs, but not for adjunct PPs. These findings indicate that the lexicalization of syntactic knowledge is limited to argument structure. More generally, this work offers additional support for the distinction between structure generation and selection, and illustrates how factors differentially affecting those processes may be explored empirically.

Keywords: parsing, argument structure, sentence comprehension, constraint-based lexicalist models

Traditional theories of language processing maintain that syntactic analysis, or parsing, is accomplished by a special-purpose mechanism using categorical rules (e.g., Frazier, 1987; Frazier & Rayner, 1982; Frazier & Clifton, 1996). Over the last ten years, the constraint-based lexicalist approach, exemplified by Trueswell, Tanenhaus, and Garnsey (1994) and MacDonald, Pearlmutter, and Seidenberg (1994), has emerged as an influential alternative and has generated considerable interest. Constraint-based parsing combines a number of features, including a highly lexicalized grammar and the simultaneous use of constraints from multiple levels of representation. One of the most intriguing ideas to

come out of the constraint-based work is the idea that parsing can be accomplished without a special-purpose parser (Bates & Goodman, 1997; Kim, Srinivas, & Trueswell, 2002; MacDonald et al., 1994). Instead, phrase structure trees or the equivalent are stored lexically, as suggested in MacDonald et al. (1994), or as implemented in a Lexicalized Tree-Adjoining Grammar (LTAG) (Kim et al., 2002; Schabes & Joshi, 1991; Srinivas & Joshi, 1999)¹, or in Vosse and Kempen's (2000) Unification Space parser. As words are recognized, stored syntactic structures are made available. Most words are associated with multiple trees, and a significant component of parsing is reduced to lexical ambiguity resolution—the selection of the appropriate lexical form from a set of alternatives. The relative frequency of the alternatives, for a given lexical item, plays a central role in the selection process, because it influences how strongly each alternative is made available (see, for example, Mac-

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¹ Although LTAG is not designed to emulate human (incremental, left-to-right) parsing, it is an example of a strongly lexicalized grammar in which the syntactic representations in the lexicon are well specified. In Kim et al. (2002), the LTAG formalisms have been utilized in a model of human parsing.

Donald, 1993; a contrasting account appears in Frazier & Rayner, 1987).

Within a fully-lexicalized approach, parsing is a matter of connecting the trees by matching nodes via a general-purpose unification mechanism (Vosse & Kempen, 2000). For example, the treelets in Figure 1 would allow for parsing of the sentence in (1) using a lexical unification mechanism alone.

- (1) Kim kissed the baby repeatedly in the park.

The NP node of the treelet in (a) would be unified with the open NP on the left side of the treelet in (d). The NP node in (e) would be unified with the NP node to the right of the verb in (c), and so forth. Note that, in (d), slots for both possible arguments and possible adjuncts are specified by *kissed*. Presumably *kissed* would be associated with a large number of other treelets identifying other possible structures not illustrated in Figure 1. Of course, not all possible treelets would be equally available. In lexicalist accounts, the availability of each alternative tree associated with a given lexical item is assumed to be weighted by frequency. This has important implications for syntactic ambiguity resolution. If the (c) form of *kissed* occurs more frequently than the (b) form, we would expect a garden path in intransitive sentences that contain a direct-object/subject ambiguity, such as *When the politicians kissed the babies cried*. In fact, frequency should influence the parsing of sentences without a temporary ambiguity as well. This is a critical point to which we will return shortly.

Including adjunct information in the lexicon, as in (d), departs from a longstanding distinction between arguments and adjuncts in linguistic theory. Arguments denote entities that are part of the essential predicate-argument structure, as in (b) and (c). For example, a kissing event includes both a kiss-er and a kiss-ee, so both *Kim* and *the baby* are arguments of *kissed* in (1). The head of a phrase—in our example *kissed* is the head of the verb phrase—specifies an argument structure (or set of argument structures) that denotes possible arguments via subcategorization frames and thematic roles. In contrast, adjuncts are modifiers such as prepositional phrases (*in the park*), adverbial phrases (*repeatedly*), and relative clauses. Contrary to (d), adjunct modifiers are not traditionally specified in the lexical entry of the noun or verb that they modify because lexical properties of the head do not restrict the type or number of possible adjuncts. Rather, adjuncts are sanctioned by general syntactic rules, such as any VP can be modified by a PP, and constrained by semantic properties, such as the disallowance of two contradictory adjuncts (ruling out *I ate in the living room in the dining room*, but allowing *I ate at the table in the dining room in my house in Ann Arbor*.) Under some approaches, these general rules have probabilities associated with them (e.g., Crocker & Brants, 2000). Lexicalist approaches that have been influenced by construction grammar, such as Jackendoff (2002), might describe these general syntactic rules for adjunct attachment as phonologically empty pieces of lexical structure. In terms of the current paper, the distinction between rules and phono-

logically empty lexical items is irrelevant; the crucial feature is that the adjunct rules or adjunct structure is not linked to particular verbs.²

If only arguments, and not adjuncts, are lexically specified, a fully lexicalized parsing system is probably not viable. An alternative is a partially lexicalized parsing system in which arguments are attached via the lexical unification mechanism, while adjuncts are attached via non-lexicalized phrase structure rules. Under this approach, the (d) treelet of Figure 1 would not be allowed. The lexical unification mechanism could still handle the attachments connecting the arguments of the verb [*Kim-kissed-the-baby*] and the preposition [*in-the-park*] using the remaining treelets, but the PP could not be attached to the VP without invoking a second rule-based mechanism for adjunct attachment. This dual mechanism account, which we will call the Argument Structure Hypothesis, suggests that processing differences might be found between arguments and adjuncts. Our approach shares much with Ford, Bresnan, and Kaplan's (1982) account which emphasized lexical preferences while maintaining a role for rule-based processes. We focus below on a fully lexicalized constraint-based model, but we will discuss the relationship of the Argument Structure Hypothesis to other theoretical approaches in the general discussion.

When considering processing differences between arguments and adjuncts, psycholinguists have given prepositional phrases (PPs) special attention (though see Liversedge, Pickering, Branigan, and Van Gompel (1998) for an exception), because it is possible to construct sentences in which a PP's status as argument or adjunct is locally ambiguous. For example, Clifton, Speer, and Abney (1991, see also Speer & Clifton, 1998) manipulated both argument status and attachment site of the critical PP, as illustrated in (2). The critical PP is underlined.

- (2) a. [VP argument] The saleswoman tried to interest the man in a wallet . . .
 b. [NP argument] The man expressed his interest in a wallet . . .
 c. [VP adjunct] The man expressed his interest in a hurry . . .
 d. [NP adjunct] The saleswoman tried to interest the man in his fifties . . .

In their experiments, attachment site influenced local reading times on the PP, but argument/adjunct status did not. VP-attached PPs were read faster than NP-attached PPs, but argument status had no effect until the region after the PP, where argument conditions were faster than adjunct conditions. Clifton et al. suggested that the PPs were initially attached to the VP (as an argument) using the Minimal Attachment Strategy (Frazier, 1978). When detailed lexical infor-

² A possibility that we do not test in the current paper is that co-occurrence frequencies between a particular adjunct and a lexical head are stored on the adjunct tree rather than on the tree associated with the lexical head. Because the number of verbs each adjunct class co-occurs with is very large, such an encoding scheme might be quite cumbersome, though logically possible.

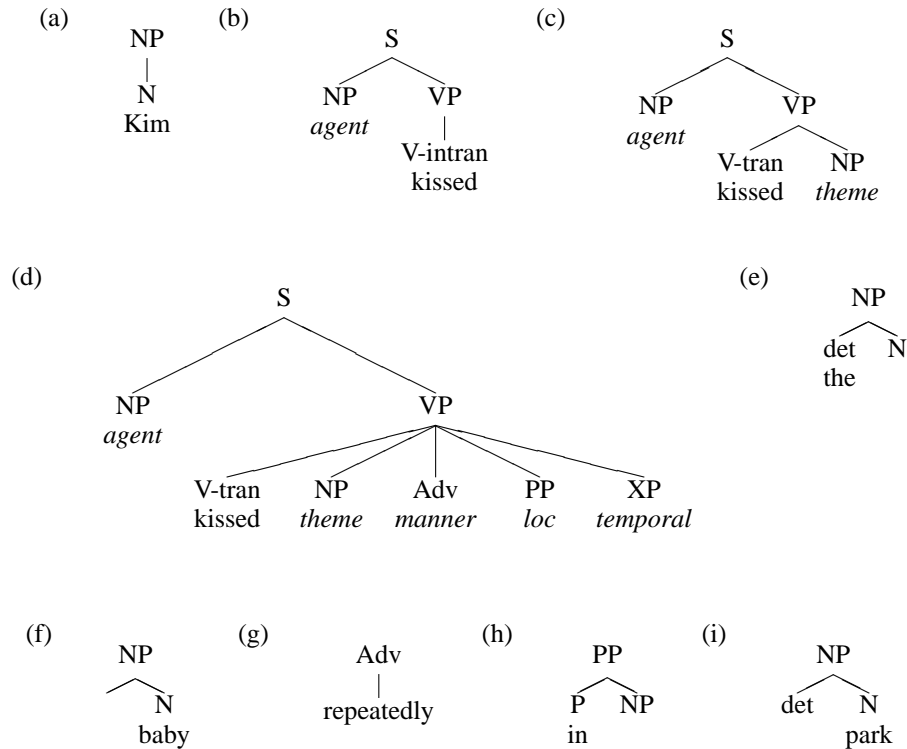


Figure 1. Lexicalized syntactic trees that would allow for the parsing of *Kim kissed the baby repeatedly in the park*.

mation was evaluated, adjuncts (and NP arguments) had to be reanalyzed, causing the downstream effect of argument status. In contrast, other researchers have found local effects of argument status (see Schutze & Gibson, 1999, and Britt, 1994). Schutze and Gibson took their findings as support for a parsing strategy that stipulates a preference for argument attachments over adjunct attachments, as in Abney (1989). What both the Clifton et al. and the Schutze and Gibson accounts share is the assumption that general (non-lexical) parsing strategies determine how PP attachment ambiguities are resolved.

In contrast to these studies which focused on ambiguity resolution, the focus of the current paper is on the mechanisms supporting PP attachment in both locally ambiguous and locally unambiguous sentences. More specifically, we explore the evidence for the specification of adjuncts in the lexical entries of verbs, taking instrument PPs as our test case. We contrast the Argument Structure Hypothesis, in which only arguments are lexically represented, with the Full Lexical Representation Hypothesis, in which both arguments and adjuncts are represented in the lexical entries of their heads. The Argument Structure Hypothesis maintains that PP attachment is accomplished via a lexicalized unification mechanism if and only if the PP is an argument, predicting that there should be frequency effects (reflecting the availability of the PP-argument form of that verb) for argument PPs, but not adjunct PPs, independent of whether or not PP

attachment is locally ambiguous.

The predictions of each hypothesis can be illustrated using the VP-attached stimuli in (2a). Under the Argument Structure Hypothesis, recognition of the verb *interest* would make available a set of trees, corresponding to possible argument structures. These would include (nonexhaustively) the argument structures shown in (3). The bracketed thematic roles and phrasal categories describe the verb's VP-internal arguments (e.g., direct object) which are underlined in the examples. The thematic role outside of the brackets describes the implicit subject of the infinitive. So in (3a), *physics* is the theme of the *interest* event and *Jim* is the experiencer, or in other words, *physics* is what interested *Jim*.

- (3) a. theme < experiencer NP > Physics managed to interest Jim.
 b. agent < experiencer NP, theme PP > The professor managed to interest Jim in physics.

The ease of integrating the VP-argument PP into the syntactic structure is a function of how available the argument structure in (3b) is, relative to other argument structures associated with *interest*. The relative frequency of each argument structure, for that verb, is one factor assumed to influence the relative availability of the argument structures. Other factors would include the thematic fit of any previously encountered arguments. If all other factors were equal, reading times on the VP-argument PP should be strongly influ-

enced by the relative frequency of (3b). In contrast, the co-occurrence frequency between *expressed* in (2c) and a manner adjunct, such as *in a hurry*, should not predict reading times on the VP-adjunct PP in (2c), because under the Argument Structure Hypothesis there is never an argument structure (or corresponding lexical tree) in which an adjunct is specified. Rather, a general (non-lexical) rule must be used to attach the adjunct PP to the developing syntactic structure.

Under the Full Lexical Representation Hypothesis, the set of trees made available by *interest* and *expressed* would include a set of adjunct options also, as in (4) and (5b-c). Following MacDonald et al. (1994), we assume that the argument/adjunct distinction would be lost, although *arguments* would correspond to those phrases that occur fairly consistently across the set of possible trees. For example, the theme PP in (2a) would probably be consistent with more lexicalized trees than the manner adjunct in (2c), and if so, should be read more quickly. Crucially, both types of PPs would be attached via the same lexical unification mechanism and therefore both should be subject to lexical frequency effects.

- (4) a. theme <experiencer NP, temporal PP > The wallet seemed to interest Jim on Sunday.
- (5) a. agent < theme NP > The man expressed his interest.
- b. agent < theme NP, manner PP> The man expressed his interest in a hurry.
- c. agent < theme NP, location PP > The man expressed his interest at the mall.

There are many potential difficulties in determining the relevant set of trees under the Full Lexical Representation Hypothesis and developing frequency-based predictions for phrases that have traditionally been called adjuncts. The stimuli in (2) are further complicated by the PP attachment ambiguity and the fact that neither PP attachment nor argument status can be determined until the whole PP is read. The current study attempts to overcome some of these problems by examining instrument PPs that have already been argued to show lexical frequency effects when used with action and psych/perception verbs. Spivey-Knowlton and Sedivy (1995) found that action verbs are much more likely to occur with instruments and other *with*-PPs than psych/perception verbs and furthermore that attachment preferences in temporarily ambiguous PPs are predicted by this frequency difference. This finding that processing of high-frequency adjuncts is easier than processing low-frequency adjuncts is consistent with the Full Lexical Representation Hypothesis, claiming that adjuncts and their frequencies are lexically encoded by verbs.

An alternative explanation of the Spivey-Knowlton and Sedivy (1995) finding, consistent with the Argument Structure Hypothesis, is that the purported lexical frequency effects are actually plausibility effects. A demonstration that Spivey-Knowlton and Sedivy's instrument PPs do not exhibit true lexical frequency effects would constitute strong evidence that no adjuncts are lexically encoded, because instrument PPs lie near the border of the argument/adjunct dis-

inction. They behave like arguments on some linguistic tests and adjuncts on others. Like Spivey-Knowlton and Sedivy, we assume that the instruments in the current study are in fact adjuncts, but some action verbs no doubt do take instrument arguments (see Koenig, Mauner, & Bienvenue, 2003).

Before describing the current study, we first review some of the literature on lexical frequency and high-level context effects. In doing so, we outline a strategy for distinguishing between the two types of constraints. This strategy depends crucially on contrasting locally ambiguous stimuli with unambiguous versions.

Constraints on Syntactic Generation vs. Constraints on Syntactic Selection

There is abundant evidence that both major category and subcategory information are specified in the lexicon and made available via word recognition (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Holmes, 1987; Holmes, Stowe, & Cupples, 1989; MacDonald, 1993; McElree, 1993; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Shapiro, Nagel, & Levine, 1993; Spivey & Tanenhaus, 1998; Tanenhaus & Carlson, 1989; Trueswell, 1996; Trueswell, Tanenhaus, & Kello, 1993) Much of this evidence comes from lexical frequency effects on syntactic ambiguity resolution. From such research, it is clear that various types of lexically-encoded frequency information can influence either the initial availability of the syntactic alternatives or the selection of the best syntactic alternative. Unfortunately, it is not possible to rely upon the timing of frequency effects to adjudicate between these two alternatives, because syntactic selection (or under a parallel account, the ranking of syntactic alternatives) is assumed to occur very rapidly.

The clearest evidence that lexical frequency influences the initial stage of syntactic analysis rests upon lexical frequency effects in unambiguous structures. For example, Boland (1997a) and Corley (1998) investigated syntactic category ambiguities like *play*. They each found that encountering a lexically ambiguous word in its less frequent form increases reading time compared to encountering its more frequent form. To illustrate, a noun-verb homograph like *play* occurs most frequently as a verb, and reading times for *play* are slower when it is used as a noun, compared to reading times for a noun-biased homograph like *duck* even when one controls for word length and overall frequency. Example sentences are provided in (6) and the treelets are illustrated in Figure 2.

- (6) a. She saw a play.
b. She saw a duck.

Frequency effects in syntactically unambiguous sentences would be expected if syntactic alternatives are encoded as alternative lexical forms (Figure 2). Generation of a syntactic representation requires accessing the appropriate lexical structure and unifying it with the developing tree. More frequent lexical forms are more accessible during word recognition. In fact, frequency effects in syntactically unambiguous sentences are the strongest possible evidence for alternative

lexical forms, because the effects must arise during lexical access and generation of syntactic structure. This distinction between the generation of syntactic structure and syntactic ambiguity resolution is explicit in some parsing theories (Altmann & Steedman, 1988; Boland, 1997b; Lewis, 1993) and acknowledged as functionally necessary in others (Spivey & Tanenhaus, 1998)³.

Boland (1997a) has shown that the selection and/or attachment of lexical forms in syntactically ambiguous sentences (i.e., the noun or verb form of *play* in *She saw her play*) is influenced by high level constraints such as discourse congruency. In contrast, lexical selection/attachment (of the noun or verb form) in unambiguous sentences such as (6) is not influenced by discourse congruency. In other words, lexical frequency affects lexical access and syntactic generation, but discourse congruency does not. Instead, discourse congruency plays an immediate role in ambiguity resolution (syntactic selection) and a relatively late role in discourse coherence processes. The syntactic component of this account is illustrated in Figure 3. To sum, immediate lexical frequency effects should be found for both ambiguous and unambiguous input, while pragmatic/plausibility constraints should influence syntactic analysis only for locally ambiguous input (as part of the selection process).

Boland and Blodgett (2001) found additional evidence that lexical frequency constraints and discourse constraints impact sentence comprehension in different ways. In an eye tracking experiment that used unambiguous target sentences like those in (6), they found lexical frequency effects only in first-pass measures of processing difficulty, while discourse congruency effects were limited to second-pass measures. In the absence of any alternative structures, discourse congruency had no impact on syntactic analysis. Rather, the second-pass effects were presumed to reflect an anomaly within the discourse-level representation. Together, these studies suggest that it is possible to temporally separate high-level effects from lexical frequency effects when using syntactically unambiguous sentences, even though lexical and discourse effects may occur simultaneously in locally ambiguous structures.

Of course, lexical frequency is not the only factor that influences syntactic generation. Under the Argument Structure Hypothesis, rule-based operations generate adjunct attachment options whenever possible. Because these adjunct rules are not associated with specific phrasal heads (e.g., specific nouns or verbs), the co-occurrence frequency between the rule and the lexical head will not influence the availability of the structure. However, its availability is assumed to be modulated by structural factors such as decay and interference (e.g., Van Dyke & Lewis, 2003; Lewis & Vasishth, 2004, submitted).

The Spivey-Knowlton and Sedivy (1995) Evidence

The claim that major category and subcategory information are lexically specified is not controversial in linguistic theory, so it is not surprising that psycholinguists have found abundant evidence of lexical frequency effects for argument

structures, in both ambiguous and unambiguous structures (e.g., Garnsey et al., 1997; Holmes et al., 1989; McRae et al., 1998; Shapiro et al., 1993; Tanenhaus & Carlson, 1989). An important question is whether comparable frequency effects can be found for adjuncts. If so, it would suggest that lexical structures contain more detail than traditional accounts of argument structure. There have been few investigations capable of addressing this question, but some positive evidence was reported in the PP adjunct study of Spivey-Knowlton and Sedivy (1995). They manipulated attachment site, using both action verbs and psych/perception verbs, in sentences like (7) and (8), respectively. Thus, it was structurally possible for the PP, which always began with *with*, to modify either the direct object NP or the entire verb phrase VP.

- (7) Action Verbs
- a. [NP-attached] The mechanic changed a tire with a faulty valve. . .
 - b. [VP-attached] The mechanic changed a tire with a monkey wrench. . .
- (8) Psych/Perception Verbs
- a. [NP-attached] The salesman glanced at a customer with ripped jeans. . .
 - b. [VP-attached] The salesman glanced at a customer with suspicion. . .

Using a phrase-by-phrase reading time paradigm, Spivey-Knowlton and Sedivy (1995) found increased processing difficulty in the action-verb sentences when the PP modified the direct object rather than the VP. For example, the PP in (7a) would have been read more slowly than the one in (7b). In contrast, they found the reverse pattern in sentences using psych/perception verbs: the PP in (8b) would have been read more slowly than the PP in (8a). The authors attributed this effect to the fact that action verbs are frequently used with VP-attached *with*-PPs that specify the instrument used to perform the action. In contrast, psych/perception verbs are rarely or never used with instruments, and their VPs are infrequently modified by any *with*-PP. Thus, the Spivey-Knowlton and Sedivy (1995) results are consistent with the Full Lexical Representation Hypothesis.

The Full Lexical Representation Hypothesis assumes that VP-attachment and NP attachment are the two structural alternatives for PP attachment in sentences like (7) and (8). These alternatives compete for support from all relevant constraints. Spivey-Knowlton and Sedivy (1995) manipulated two of these constraints: the frequency with which a *with*-PP is attached as a VP adjunct for that verb class and definiteness of the direct object NP. Other potentially relevant

³ The syntactic generation component in our approach could be decomposed into at least three parts: frequency-weighted access to the appropriate lexical structure(s), rule-based generation of other grammatical attachments, and a unification mechanism for integrating new structural information into the developing tree. Although we are not specifying here the particular mechanisms responsible for each of these tasks, a possible mechanism for the first subcomponent is the lexical disambiguation module in Crocker and Corley's (2002) model.

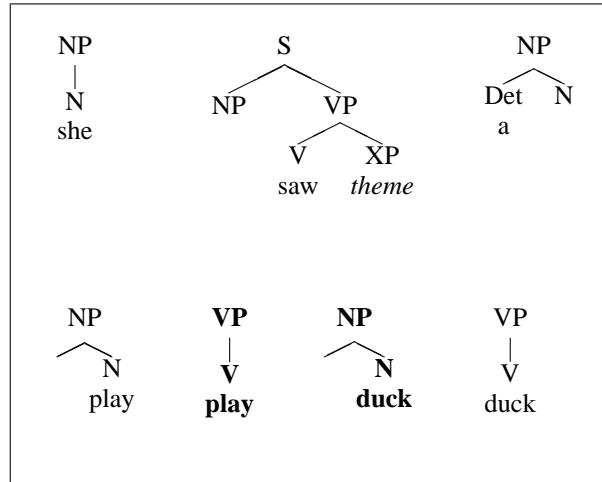


Figure 2. Syntactic alternatives encoded in alternative lexical forms for *She saw a...play/duck*. The dominant (higher frequency) forms for *duck* and *play* are shown in boldface.

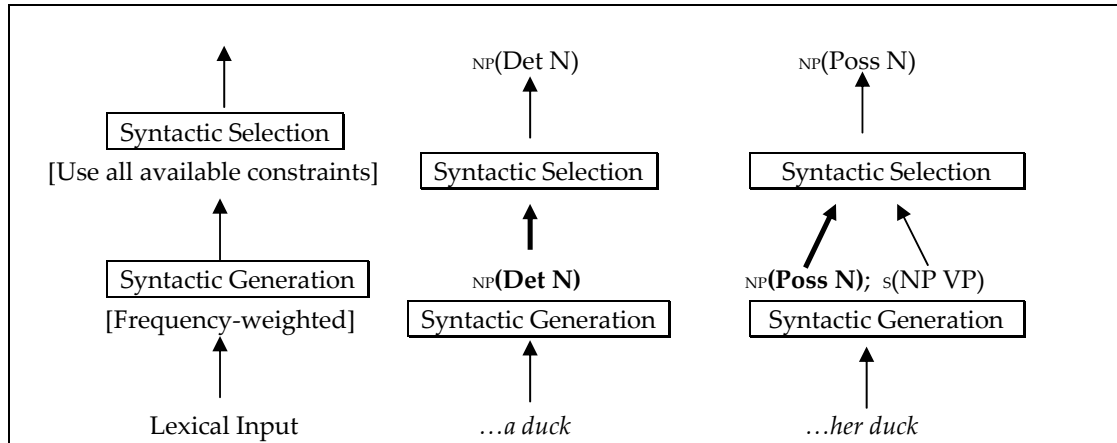


Figure 3. The architecture of a parsing model distinguishing generation and selection (left). The representations generated by the model are provided for an unambiguous example (center) and an ambiguous example (right).

constraints that were not intentionally manipulated include the frequency that a *with*-PP occurs as an NP adjunct for the direct object, the plausibility of NP and VP modification using a *with*-PP, and the ease of interpreting instrument PPs versus other types of modifiers. The two structural alternatives, along with most of the constraint information, would become available at the preposition *with* in (7) and (8). In the conditions that we highlighted above, Spivey-Knowlton and Sedivy (1995) assumed that NP-attachment won for psych/perception verbs and VP-attachment won for action verbs, due to the verb bias. Thus, their account suggests that adjunct slots, and the frequencies with which they are filled, are encoded in the lexical entry of verbs. However, there are several reasons to be cautious about drawing that conclusion.

First, under any constraint-based approach, the resolution of a syntactic ambiguity can be influenced by constraints from any level of representation. The fact that the Spivey-

Knowlton and Sedivy (1995) effects were found on the PP does not, by itself, entail that these are lexical frequency effects. It is just as likely that a difference in the plausibility of the structural alternatives caused the observed pattern. As we have demonstrated above, one must use locally unambiguous structures to isolate lexical frequency effects from higher level effects.

Second, the status of instrument PPs as adjuncts or arguments is a long-standing controversy in linguistics, which remains unresolved (e.g., Gruber, 1965; Larson, 1988; Marantz, 1984). Thus, a demonstration that instrument PPs are lexically encoded would not provide convincing evidence that most adjunct PPs are lexically encoded. More importantly, the design of the experiment cannot support any conclusions about verb class effects. Because verb class was not manipulated within any single experiment and the lexical content of the PPs across the two sets of stimuli was not controlled, the critical interaction between verb class and

attachment site could not be tested.

Furthermore, the fact that psych/perception verbs occurred only rarely with adjunct *with*-PPs does not by itself generate the prediction that NP-attachment should be easier than VP-attachment in sentences like (8). Under a frequency-based account, the ease of NP-attachment should be predicted most strongly by the frequency with which the direct objects take *with*-PP adjuncts—something that was apparently neither measured nor controlled across verb types. Thus, the critical frequency-based prediction for verb class was simply that VP-attachment should be easier in sentences like (7b) than (8b). Unfortunately, this prediction was never tested in Spivey-Knowlton and Sedivy (1995), because no experiments included verb type as a variable.

Finally, one cannot simply conclude that Spivey-Knowlton and Sedivy (1995) found effects of verb bias, because the semantic contribution of the PP was quite different for the action verbs (where the VP-attached PP provided an instrument of the action) compared to the psych/perception verbs (where the VP-attached PP usually described the agent's manner of performance). Perhaps it is simply easier to process instrument PPs than manner PPs. This confound is difficult to avoid, and we will discuss it further after presenting our results.

Experiment 1

The Spivey-Knowlton and Sedivy (1995) results imply an interaction between verb type and attachment site during the PP region, at least for their temporarily ambiguous materials, illustrated by (7) and (8) above. They did not test this directly, because verb type was not manipulated within their experiments. We expect to see such an interaction in our temporarily ambiguous conditions, which are very similar to their materials. If the expected interaction is observed, we can address the primary goal of the experiment, which is to distinguish between two alternative explanations for the interaction.

The Spivey-Knowlton and Sedivy (1995) account of the interaction is that recognition of an action verb makes available a lexical structure that selects a *with*-PP; if such a structure is made available at all in the case of psych/perception verbs, it is much weaker. This is consistent with the Full Lexical Representation Hypothesis. Under the Argument Structure Hypothesis, adjunct attachment slots are not represented in the lexical entries of verbs. Therefore, both NP and VP-attachment options are generated by rule regardless of verb type, and syntactic selection processes must choose the best candidate. As in constraint-based approaches, we assume that syntactic selection is influenced by high-level constraints, e.g., pragmatic knowledge. In fact, VP-attachment probably receives more pragmatic support in the action verb conditions than in the psych/perception verb conditions: facts about the world dictate that mechanics typically use tools to change tires, whereas salesmen do not use any kind of instrument to glance at customers. Thus, all else being equal, VP-attachment of a *with*-PP is more likely to be selected for action verbs than for perception

verbs, even before the prepositional object is encountered. Granted, VP-attached *with*-PPs don't always take the role of instrument. Both verb classes also allow *with*-PPs denoting manner (e.g., *changed/acknowledged with a smile*) or a co-participant (e.g., *with his brother*). *With* could also be used here as a subordinating conjunction (e.g., *with his wife away on business*). Because each of these possibilities is a relatively unconstrained adjunct, we assume that they are evenly distributed for the two verb classes.

In order to distinguish between these two explanations, we included a set of conditions in which all else was not equal. We created maximally unambiguous conditions, in which the attachment site was either obligatorily on the NP (9) or strongly constrained toward the VP (10). Although the VP-attachment condition is not, strictly speaking, unambiguous (as will be discussed in the materials section), we will nevertheless refer to both the NP-attached and VP-attached conditions illustrated in (10), (9), and (11) as unambiguous. The central predictions focus on (9). If the Spivey-Knowlton and Sedivy (1995) effect was due to the strength with which the necessary lexical forms were accessed from the lexicon, then the verb class effect should be found for (9), as well as for the (7b)/(8b) contrast. That is, reading times for the PP should be faster in the action verb condition than in the psych/perception verb condition. On the other hand, if the verb class effect is actually the result of pragmatic influences on syntactic selection (ambiguity resolution), the effect should be very reduced in (9). The conditions in (10) do not contain the critical action and psych/perception verbs and were included primarily to balance the experimental design.

- (9) Unambiguous NP-Attachment
- a. The mechanic's next project was a tire with a faulty valve...
 - b. The saleswoman's concern was a customer with ripped trousers...
- (10) Unambiguous VP-Attachment
- a. [Action] The tire that the mechanic changed with a monkey wrench...
 - b. [Psych/Perception] The customer that the saleswoman acknowledged with a polite nod...

In reasoning thus far, we have followed Spivey-Knowlton and Sedivy (1995) in assuming that the instrument PPs are adjuncts rather than arguments. If in fact, instruments are arguments, then we would expect to find argument structure frequency effects for unambiguous structures like (9). Thus, we need an additional pair of conditions, in which the PP is uncontroversially an argument. In (11), the PP is the indirect object of the verb. However, the verb in (10a) takes an indirect object more often than the verb in (10b). We expect, therefore, that the argument structure with the indirect object slot should be more accessible for verbs like *delegate* than for verbs like *suggest*, and reading times of the PP in (10a) correspondingly faster.

- (11) Datives: VP-Attachment

- a. [High freq] The chores that the parents delegated to their kids were painless.
- b. [Low freq] The chores that the parents suggested to their kids were painless.

Methods

Participants. Forty undergraduates from Rutgers University completed the experiment. In both experiments, all were native speakers of English, with no reading disabilities, who participated for course credit in an introductory psychology class.

Materials and Design. There were three sets of critical items, corresponding to the three critical verb types: action verbs, psych/perception verbs, and dative verbs. The first two verb types were crossed with both PP attachment site and degree of local ambiguity. We included only two (high vs. low indirect object frequency) unambiguously VP-attached conditions for the dative verbs, as illustrated in (11). Examples of all ten conditions are provided in Table 1. Slashes between words demarcate phrases used for the phrase-by-phrase presentation. An example comprehension question is provided for the dative item. The full set of experimental stimuli is in Appendix A.

We adapted the action verb and psych/perception verb materials from Spivey-Knowlton and Sedivy (1995) (who in turn, had adapted their action verb stimuli from Altmann & Steedman, 1988). In our stimuli, all direct object NPs were indefinite, because Spivey-Knowlton and Sedivy (1995) found a local NP-attachment advantage for psych/perception verbs only when the PP followed an indefinite NP. We made some further adjustments to the Spivey-Knowlton and Sedivy (1995) stimuli in order to match the stimuli across verb type as closely as possible. First, we omitted eight of the original 32 action verb items, and added eight psych/perception verb items, resulting in 24 items for each verb type. Some action verbs had been used twice in Spivey-Knowlton and Sedivy (1995), and we eliminated duplicates as much as possible. Second, we replaced particle verbs (e.g., *blew open*) with simple verbs from the appropriate class. Six of the original 16 psych/perception verbs were replaced in this way. (One of the verb + preposition items in the action verb group, *cut through*, slipped through our filter.) Third, the number of words and characters in the critical PP was matched across conditions (mean = 3.5 words in all conditions; NP-psych = 19.3 char, VP-psych = 19.5 char; NP-Act = 18.5 char; VP-act = 18.4 char). Fourth, we modified the post-PP region, so that all items contained a two-word, temporal NP modifier (e.g., *this morning*) immediately following the PP. We did this to control for processing difficulty in the PP+1 region, because we anticipated lingering effects of the experimental manipulations. Word frequency, as well as length, is known to influence reading time. The adjectives in the critical PP had mean Kucera and Francis (1967) frequencies of 177 in the NP-psych condition, 232 in the VP-psych condition, 81 in the NP-action condition, and 78 in the VP-action condition. The corresponding means for the nouns were 106, 103, 41, and 39, respectively. Thus, the

perception/psych verb conditions contained somewhat more frequent words than the action verb conditions, but the frequencies were closely matched across attachment conditions within verb class.

Unambiguously NP-attached versions of both the action verb items and the psych/perception verb items were formed by replacing the critical verb with a copula, which cannot be modified by a PP across an intervening NP. This required changing the subject NP as well. Because the critical verb was absent, any differences found between the unambiguous NP-attached conditions cannot be due to the differences in the verb-based preferences that drive most of our predictions.

Strongly biased VP-attached conditions were formed by fronting the direct object, so that the critical verb was in a relative clause. Structural factors such as recency and complexity lead to the VP-attachment preference. However, many speakers find some NP-attached PPs grammatical as well. Some examples are provided in (12).

- (12) a. The toddler that the saleswoman noticed with a runny nose and a forlorn look was lost.
- b. The pizza that the girl sliced with pepperoni and extra cheese smelled delicious.
- c. The ending that the director suggested to the play was the favorite among the cast members.

Nevertheless, the possibility that a small proportion of the PPs in our VP-attached conditions could be initially attached to the NPs only adds noise to our data—it does not introduce a confound that affects the interpretation of the results.

The dative conditions had the same form as the unambiguous VP-attached conditions. Sixteen item sets were formed using 31 dative verbs (*suggested* was used twice). The verbs were divided into high and low frequency, on the basis of how frequently they were used with indirect objects in a set of completion measures collected by Boland, Tanenhaus, Garnsey, and Carlson (1995) and Boland (1997b). The high frequency dative verbs were used with dative PPs 45% of the time, while the low frequency datives were used with dative PPs only 12% of the time.⁴ Statistics were collected from the Brown corpus to provide converging evidence: the high frequency dative verbs were used with recipient PPs 26% of the time, while the low frequency datives were used with recipient PPs 8% of the time. The nouns in the critical PP had a mean Kucera and Francis (1967) frequency of 89, falling between the frequency of the nouns in the action verb and psych/perception verb conditions.

The 64 critical items were randomly ordered with 77 filler items, for a total of 141 sentences. There were four conditions of each action verb item and each psych/perception verb item, so four experimental lists were created by rotating the conditions across the four lists. Each participant saw only one list. In this way, each participant saw equal numbers of items from each condition, but only one version for each item. Because there were only two conditions for the da-

⁴ Table 3 provides complementary statistics for the likelihood of a PP beginning with *to* (though not necessarily as a recipient) or a recipient phrase (either an NP or a PP).

Table 1
Example stimuli with phrase divisions

Action verbs	Temporarily ambiguous	NP-attached	The mechanic / changed / a tire / with a faulty valve / this morning / but it took / a while.
		VP-attached	The mechanic / changed / a tire / with a monkey wrench / this morning / but it took / a while.
Action verbs	Unambiguous attachment	NP-attached	The car's problem / was / a tire / with a faulty valve / this morning / but the mechanic / fixed it.
		VP-attached	The tire / that the mechanic / changed / with a monkey wrench / this morning / had a faulty valve / on it.
Psych/perception verbs	Temporarily ambiguous	NP-attached	The saleswoman / acknowledged / a customer / with ripped trousers / Monday evening / and then / walked away.
		VP-attached	The saleswoman / acknowledged / a customer / with a polite nod / Monday evening / and then / walked away.
Psych/perception verbs	Unambiguous attachment	NP-attached	The saleswoman's concern / was / a customer / with ripped trousers / Monday evening / but he / walked away.
		VP-attached	The customer / that the saleswoman / acknowledged / with a polite nod / Monday evening / had already / walked away.
Dative verbs	Unambiguously VP-attached	High freq	The chores / that the parents / delegated / to their kids / last week / were very easy / to accomplish.
		Low freq	The chores / that the parents / suggested / to their kids / last week / were very easy / to accomplish.
Q: Were the chores simple? YES			

tive verb items, those conditions went through two rotations across the four lists. That is, each dative item appeared in the same condition on both List 1 and List 3, and appeared in the other condition on List 2 and List 4. Yes/no comprehension questions followed 76 of the sentences, to insure participants were reading for comprehension. The intent was to query the participants about half the time, with questions distributed randomly throughout the stimulus list. None of the questions after critical items referred to the materials in the critical PP (see Table 1 for an example of a question for a dative item.) For filler items, questions did sometimes probe the content, but not the attachment, of a PP.

Plausibility norming. To assess possible differences in the plausibility of our materials that might affect the interpretation of our results, we obtained plausibility ratings from 32 University of Michigan students who did not participate in either of the primary studies. Each experimental item was transformed into an unambiguous sentence that conveyed the same content as the experimental item up to the end of the critical PP. In this way, we were able to assess possible perceived differences in the plausibility of the modifications independently of garden paths or other ambiguity effects.

To illustrate the materials construction, all four conditions of an item from the original stimulus list are provided in (13):

- (13)
- a. [Ambig, NP attached] The executive sought a promotion with a salary increase last year but he was fired instead.
 - b. [Ambig, VP attached] The executive sought a promotion with bold determination last year but he was fired instead.
 - c. [Unambig, NP attached] The executive's goal was a promotion with a salary increase last year but he was fired instead.
 - d. [Unambig, VP attached] The promotion that the executive sought with bold determination last year did not come to pass.

To assess the plausibility of *with a salary* modifying a *promotion* in (13a), we replaced the PP with a relative clause containing the same content, as in (14). The use of the relative clause forces modification of the NP.

- (14) [NP modification/content verb] The executive sought a promotion that had a salary increase.

To assess effects of the slightly different lexical content and the copula verb introduced in the unambiguous NP-attached version, we used the same structure as in (13c), substituting the relative clause for the PP:

- (15) [NP modification/copula verb] The executive's goal was a promotion that had a salary increase.

There was no difference in lexical content between the ambiguous (13b) and unambiguous (13d) VP-attached versions up to the end of the PP, so (16) was used to assess the plausibility of the intended interpretation for both VP-attachment conditions.

- (16) [VP modification] The executive sought a promotion, and he did so with bold determination.

The action verb materials were similarly modified. The dative conditions were used in unmodified form. This produced 64 critical items that were mixed with the same 76 filler items as the main experiments, ensuring that the background context was the same across the experiments. There were three conditions of each action verb item and each psych/perception verb item, so three experimental lists were created by rotating the conditions across the four lists. Each participant saw only one list. In this way, each participant saw equal numbers of items from each condition, but only one version for each item.

Participants rated each sentence on a scale of 1 (completely implausible) to 7 (completely plausible). Table 2 summarizes the mean ratings. Participant and item means were submitted to 8 (condition) \times 3 (list) ANOVAs, which revealed no differences across conditions ($F_s < 1$, $p's > .40$).

It is important to note that these ratings assess the perceived plausibility of the content of the PP modification. They are not online measures that can detect differences in the plausibility of partial interpretations that we hypothesized above may guide the selection process during PP attachment in locally ambiguous cases.

Corpus Data. To assess the frequency with which our experimental verbs occurred with the target constituent, we searched the Brown corpus for every past tense token (up to 100 tokens) of each verb. We then computed the proportion of tokens used with VP-attached *with*-PPs for the transitive verbs and VP-attached *to*-PPs for the dative verbs (including PPs that were not instruments/recipients). We also computed the total percentage of tokens used with an instrument for action verbs and a recipient for dative verbs (including instruments/recipients that were not formulated like the target PP—e.g., *The man cleaned his gun using a rag; The woman gave the girl a cookie*). For the psych/perception verbs, we calculated the proportion of tokens used with a constituent that, in our judgment, satisfied the same role as the target PP. The mean proportions by verb class are given in Table 3.

The proportion of action-verb usage that included a *with*-PP or an instrument role was lower than the frequency of a *to*-PP or a recipient role in our low frequency dative condition. This may be surprising, given that Spivey-Knowlton

and Sedivy (1995) found 90% VP-attachment of *with*-PPs for their action verbs in sentence completions. The discrepancy is explained because their participants were completing fragments that included the preposition *with*. Thus, Spivey-Knowlton and Sedivy (1995) were measuring how likely participants were to resolve an attachment ambiguity as VP-attached. In contrast, our corpus data provides an estimate of how frequently VP-attached *with*-PPs or *to*-PPs occur with these verbs.

Procedure

In order to replicate Spivey-Knowlton and Sedivy (1995) as closely as possible, we used a phrase-by-phrase reading time paradigm, just as they did. The phrase divisions for each condition were illustrated in Table 1. The first four conditions are taken from Spivey-Knowlton and Sedivy (1995), so we used the same phrase divisions that they selected, except that we had one additional post-PP region: Subject, verb, direct object, PP, PP+1, PP+2, PP+3. In our new conditions, we created similar phrase regions. We collected reading times for the first six phrases in each critical sentence, ignoring only the last region.

Participants pressed a key on a response box to see each phrase, presented one at a time, moving window style. They first completed eight practice trials. If participants had no questions or problems, they then completed the experiment proper. All participants completed the experiment in less than thirty minutes.

Results

Comprehension accuracy was 90.1%. Mean reading time was computed by participant and by item for each condition at each region. Reading times greater than 2.5 standard deviations from the participant or item mean were considered outliers and were replaced with the cutoff value. Participant means were analyzed in standard factorial ANOVAs. For item analyses, we performed an analysis of covariance (ANCOVA) using phrase length as a covariate.⁵

⁵ Each item analysis was performed as follows. First, we fitted a complete model including all interactions with length. The length variable was centered first by subtracting its mean. Interactions with length were noted (if any) and included in a simpler model of the form:

$$\text{length} + \text{interactions with length} + \text{ambiguity} (2) \times \text{verb} (2) \times \text{attachment} (2) \times \text{list} (4)$$

The length covariate was entered into the model first. This analysis has two advantages. First, it eliminates any possible confounds with length from the effects of our factors of interest: we can be sure that any significant effects we find are not due to (linear) effects of length variance. Second, given that there is a small amount of length variance present in the materials, we can increase statistical power by eliminating noise due to this variance. By testing for and including interactions with length in the final fitted model, we do not violate the assumptions of parallelism inherent in simple ANCOVA models. For most of our analyses, the ANCOVA led to the same interpretation as an ANOVA ignoring length, but there were a few examples of both marginal effects becoming significant (because of

Table 2
Mean plausibility ratings for unambiguous versions of the experimental materials

	NP modification (content verb)	NP modification (copula verb)	VP modification
Action verbs	5.33 (1.71)	5.40 (1.74)	5.33 (1.78)
Psych/Perception verbs	5.46 (1.71)	5.43 (1.77)	5.41 (1.79)
Dative, hi-freq (to)			5.63 (1.57)
Dative, lo-freq (to)			5.46 (1.66)

Note: Standard deviations are given in parentheses.

Table 3
Corpora proportions for the transitive and dative verbs.

Verb Class	VP-attached Phrases With...		
	Same Preposition	Same Thematic Role	Thematic Role
Action	.06 (.11) (with)	.07 (.13)	instrument
Psych/Perception	.00 (.02) (with)	.06 (.11)	varied
Dative, hi-freq	.28 (.26) (to)	.41 (.35)	recipient
Dative, lo-freq	.19 (.27) (to)	.14 (.25)	recipient

Note: Standard deviations are given in parentheses.

We present the data from all the regions in Figures 4–6, but we focused our analysis on the PP region, where Spivey-Knowlton and Sedivy (1995) found their critical effects and where all of our predicted effects were anticipated. The first portion of the results section focuses on the action and psych/perception verb conditions. The findings for the dative conditions are presented later.

Global ANOVA/ANCOVA at PP region. Our most global prediction was an interaction of ambiguity, verb type, and attachment site during the prepositional phrase region. Such an interaction was found in a 2 (ambiguity) by 2 (action vs. psych/perception) by 2 (attachment site) by 4 (list) ANOVA by participants [$F_1(1, 36) = 4.92, p < .05$], and in the ANCOVA by items [$F_2(1, 35) = 5.17, p < .05$]. The predicted pattern was an interaction of verb type and attachment site for the ambiguous conditions, but no such interaction for the unambiguous conditions. Therefore, additional analyses were carried out separately on the ambiguous and unambiguous conditions.

Replication of Spivey-Knowlton and Sedivy (1995) verb-class effect on ambiguous stimuli. The four temporarily ambiguous conditions that were repeated from Spivey-

Knowlton and Sedivy (1995) were analyzed to confirm the expected interaction between verb-type and attachment. A summary of the data from these conditions is provided in Figure 4. Participant means were submitted to a 2 (action vs. psych/perception) by 2 (attachment site) by 4 (list) ANOVA over reading times during the PP. Items means were submitted to an ANCOVA with length as a covariate as described in footnote 5. We found the expected interaction between verb and attachment by participants, but the effect was not reliable across items [$F_1(1, 36) = 8.49, p < .01$; $F_2(1, 39) = 1.96, p > .10$]. In planned comparisons, a verb class effect was found by participants in VP-attachment conditions ($t_1(39) = 3.95, p < .01$). The effect did not quite reach significance by items [$F_2(1, 38) = 3.78, p = .06$]. It was totally absent by both participants and items for the NP-attachment conditions [$F_s < 1$].

Disappearance of verb class effect in unambiguously attached adjunct PPs. The data from the four unambiguous conditions of the action and psych verb items are summa-

reduced variance due to length), and significant effects becoming marginal (because the effect variance was partially correlated with length).

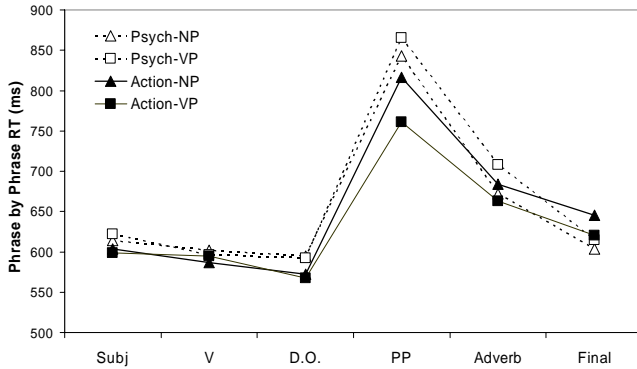


Figure 4. Mean phrase-by-phrase reading times for the temporarily ambiguous stimuli, the same conditions used in Spivey-Knowlton and Sedivy (1995).

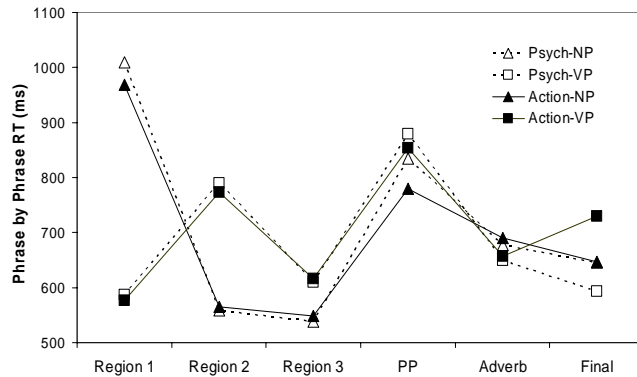


Figure 5. Mean phrase-by-phrase reading times for the unambiguous versions of the Spivey-Knowlton and Sedivy (1995) stimuli.

ized in Figure 5. The ANOVA/ANCOVA confirmed that there was no interaction of verb type and attachment site [$F_s < 1.0$]. The lack of an interaction, taken together with the presence of a verb by attachment interaction for the ambiguous conditions, and a three-way interaction with ambiguity in the global ANOVA, indicates that the verb-type effect for the VP-attachment conditions was quite diminished compared to the ambiguous VP-attached conditions in Figure 1. Furthermore, a planned comparison revealed that the NP-attachment was faster for the action verb condition than the psych verb condition in the analysis by participants [$F_1(1, 39) = 6.25, p < .05; F_2(1, 32) = 1.04, p > .10$].

The data for the four unambiguously VP-attached conditions are summarized in Figure 6. Note that the figure illustrates the two dative conditions (high vs. low frequency of dative PP) and repeats the unambiguous VP-attachment conditions from Figure 5. Here, the action verbs are described as high PP frequency and the psych verbs are described as low PP frequency. We submitted the participant means for these four conditions to a 4 (list) by 2 (verb) by 2 (frequency) ANOVA by participants⁶ at the critical PP. Reading times were much faster for the dative conditions overall [$F_1(1, 36) = 72.87, p < .01$], probably because those PPs

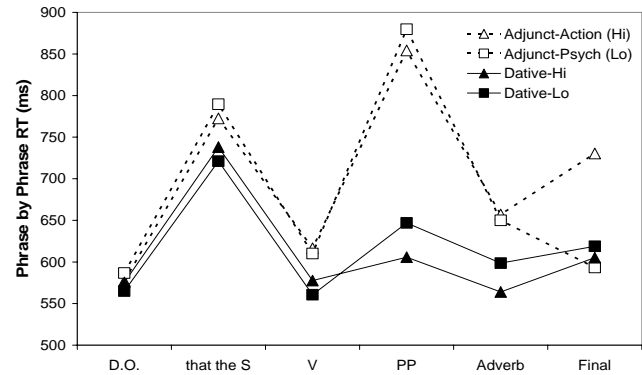


Figure 6. Mean phrase-by-phrase reading times for the unambiguous versions of the VP-attached conditions.

were somewhat shorter. There was a marginal interaction between verb type and frequency [$F_1(1, 36) = 3.56, p < .10$]. In planned comparisons, the high frequency dative condition was reliably faster by both participants and items than the low frequency dative condition during the PP region [$t_1(39) = 2.54, p < .05$]. Crucially, this confirms the expected frequency effect for VP arguments. In contrast, there was no difference between the action verbs and psych verb conditions at either the PP or the following region ($t's < 1.0$). Thus, VP adjuncts did not give rise to a similar frequency effect.

Discussion

Using temporarily ambiguous stimuli and adjunct *with*-PPs that were similar to the stimuli used in Spivey-Knowlton and Sedivy (1995), we replicated their finding that verb class (action vs. psych/perception) influences ease of PP attachment to the VP. However, the verb-class effect disappeared when using maximally unambiguous structures. The fact that degree of ambiguity modulates the effect indicates that this verb-class effect occurs at the level of syntactic selection (when there is a local syntactic ambiguity) rather than at the level of lexical access and syntactic generation. In other words, the lexical entries for these action and psych/perception verbs do not index a syntactic form corresponding to [V NP *with*-PP] that is strengthened each time such a structure is encountered, thereby making the syntactic frame more accessible during lexical access for verbs that are frequently used in this manner.

In contrast to the findings for adjunct *with*-PPs, our findings confirm that dative verbs do index a [V NP *to*-PP] form that is strengthened with frequency of use, and thereby becomes more accessible for verbs that are frequently used with a dative PP. The claim that these dative verbs index a prepositional indirect object was not actually in doubt, because the PPs are uncontroversially considered to be arguments of

⁶ We did not perform an ANOVA by items because the number of item groups and items per cell differed for dative and transitive materials.

the verb, and therefore must be lexically represented. The important point here is that the syntactic form is more accessible for verbs that occur in this form frequently. Thus, a frequency effect was found for dative verbs, even though the PP attachment was unambiguous. This difference between transitive and dative verbs was predicted by the Argument Structure Hypothesis, which maintains that argument frequency, but not adjunct frequency, is lexically represented as weighted subcategorization frames.

Of course, one might argue that the *with*-PP syntactic frames were too weakly represented to produce robust frequency effects. As shown in Table 3, our dative verbs appear more frequently with *to*-PPs than our transitive verbs appear with *with*-PPs. If the reason that we did not find frequency effects for *with*-PPs is that their overall frequency is too low, it also compromises Spivey-Knowlton and Sedivy's (1995) interpretation of their results. Thus, our reinterpretation of the Spivey-Knowlton and Sedivy (1995) results remains unchanged. The verb class effects found by Spivey-Knowlton and Sedivy (1995) and replicated here in our temporarily ambiguous stimuli did not arise at the level of syntactic generation. We know from our unambiguous conditions that the VP-attachment structure was generated just as easily for the psych/perception verbs as for the action verbs. The difference between the action verb conditions and the psych/perception verb conditions in the ambiguous stimuli, together with the lack of such a difference in the unambiguous stimuli, demonstrates that one must be very careful in drawing inferences about the lexicalization of syntactic information on the basis of data gathered using temporarily ambiguous materials.

It should also be noted that the semantic contribution of the VP-attached PP was quite different between the action verbs and the psych/perception verbs, both in Spivey-Knowlton and Sedivy (1995) and in the current experiment. Most of the PPs in the action verb set served as VP instruments, whereas the PPs in the psych/perception verb set were most often describing the agent's state of mind (e.g., *with bold determination*). It is possible that some of the differences in the temporarily ambiguous stimuli are actually due to differences in processing the PPs themselves (e.g., abstract vs. concrete), rather than differences in verb class. However, here again the comparison between the ambiguous and unambiguous stimuli is instructive. There were no differences in processing difficulty for the PPs in the unambiguous stimuli, so it is unlikely that differences in ease of processing of the PPs themselves caused the effect in the ambiguous stimuli.

There were two ways in which our data did not mirror the pattern found by Spivey-Knowlton and Sedivy (1995). First, Spivey-Knowlton and Sedivy (1995) found a preference for NP-attachment in their psych/perception verb experiment, but we did not replicate this finding. In fact, this discrepancy is not crucial, because an NP-attachment preference is predicated on the NP, not the verb. In adding some new items, we may have selected direct object NPs that were less naturally used with *with*-PPs, thereby diminishing the NP-attachment preference. Second, the interactions between verb class and

attachment site in the transitive verb stimuli were not reliable in the items analysis. In fact, Spivey-Knowlton and Sedivy (1995) never looked for such an interaction so we do not know whether our findings actually differ in this respect. Nevertheless, the lack of an effect in the items analysis suggests some variability in how effectively each item biased VP (or NP) attachment. The instability of the item analysis was not due to the introduction of phrase length as a covariate; the F-value was essentially identical with and without length (1.96 vs. 1.89).

Our results strongly suggest that the verb-class effects in the temporarily ambiguous stimuli, which were initially reported by Spivey-Knowlton and Sedivy (1995) and replicated here, must be effects on syntactic selection rather than the initial generation of syntactic structure. Thus, pragmatic differences in the felicity of VP and NP modification could influence the selection process.

We believe that the cause of the verb-class/frequency differences reported by Spivey-Knowlton and Sedivy (1995) are undoubtedly pragmatic constraints that also guide syntactic selection. If so, these pragmatic constraints should affect syntactic processing slightly later than effects of lexical frequency. We explore this hypothesis in Experiment 2.

Experiment 2

For our second experiment, we used slightly shorter versions of the Experiment 1 stimuli in an eye-movement paradigm. We expected to replicate the effects found in Experiment 1. In addition, we wished to contrast the various dependent measures available from the eye-movement record in order to better understand the timing of the lexical and (presumably) pragmatic effects observed in Experiment 1.

Methods

Participants. Twenty-four students from the University of Louisiana at Lafayette participated in this experiment for partial credit in an undergraduate psychology course.

Materials. This experiment used the same stimuli as Experiment 1, except that the stimulus set was abbreviated in three ways. First, the final two regions of each sentence were omitted (See Table 1). In all cases, the sentences ended with the adverbial phrase. The phrase divisions in Experiment 1 still defined the regions of analyses here. Second, the number of filler sentences was reduced to 55 (from 77 in Experiment 1) in order to shorten the experiment to 120 trials. Finally, the number of comprehension questions was reduced to 55 (from 76).

Procedure. A dental impression was made for each research participant and attached to a "bite bar" in order to hold the participant's head in a fixed position. We also used a stationary headrest and an adjustable chin-rest to help secure the head in a comfortable fashion. Eye fixations were measured using a Dr. Bouis monocular oculometer (Karlsruhe, Germany). This system has a resolution of 1 to 5 minutes of arc. The monitor was positioned 71 cm from the eye, such

that the visual angle of each character was approximately 15 minutes of arc. The device provides two voltage outputs, corresponding to eye position along the X and Y axes. The sensor of the apparatus was first roughly aligned by mechanical means. It was then further adjusted to give zero-output voltages when the participant looked straight ahead, as well as balanced positive and negative voltages when the participant looked at equidistant points along the X and Y axes. The experimenter then ran a calibration routine during which the participant was asked to fixate on nine disparate points on the computer screen in order to establish the relationship between X/Y voltages and screen position. Unless this could be done with an error rate of less than ten pixels in each dimension, the experiment was aborted.

After successful calibration, participants completed ten practice trials. The participants were instructed to read each sentence as it appeared and be prepared to answer comprehension questions after some of the trials. Half of the practice trials were followed by a yes/no comprehension question; participants pressed a button to indicate their answer. The set-up was re-calibrated between the practice trials and the main experiment, using the same criterion. During the experiment, analog eye position was digitized (1 kHz) and converted to screen coordinates. Each sentence was presented on the screen in its entirety, on a single line. Forty-six percent of trials were followed by a yes/no comprehension question. The question appeared on the screen with the words *NO* and *YES* spaced widely on the line below. Participants pressed the left response button for *NO* and the right response button for *YES*.

For each trial, the screen position and duration of each fixation were computed and stored. The set-up was recalibrated periodically during the experiment to ensure accurate tracking of the eye movements. The experiment took less than an hour.

Results

Mean accuracy on comprehension questions was 85% correct. We analyzed data from four dependent measures. The first-pass reading times are indicative of processing difficulty during initial processing (Frazier & Rayner, 1982). This measure includes multiple fixations during a region if such fixations occur prior to leaving the region. We calculated the probability of a first-pass regressive eye movement as the proportion of trials on which the reader left the region and returned to an earlier region (Frazier & Rayner, 1982). The regression-path duration includes all first-pass fixations and any time spent in earlier regions prior to fixations to the right of the current region (Brysbaert & Mitchell, 1996; Konieczny, Hemforth, Scheepers, & Strube, 1997; Liversedge, 1994; Traxler, Bybee, & Pickering, 1997). Finally, total times reflect all fixations in a region. This is the most global measure of local processing difficulty because it includes all secondary fixations in a region.

As in Experiment 1, we began by looking for a three-way interaction of verb class, attachment site, and ambiguity, which is localized to the PP region. Therefore, we present

the data for the two regions before and the region after the PP region in Figures 7 and 8, although we focused the analysis on the PP region. We omitted data from the initial region because long reading times in the unambiguously NP-attached conditions would have required us to compress the scale, making the effects at the PP region difficult to see. This portion of the analysis ignores the two dative conditions. The analysis of the dative conditions is presented at the end of the results section.

Global ANOVA/ANCOVA at PP region. The ambiguous and unambiguous versions of the action-verb and psych/perception-verb conditions were first submitted to 2 (ambiguity) by 2 (verb type) by 2 (attachment site) by 4 (list) ANOVA and ANCOVAs for each of the dependent measures. As shown in the upper portion of the Figures 7 (ambiguous conditions) and 8 (unambiguous conditions), both the first-pass times and the total times appear to exhibit the predicted three-way interaction of ambiguity, attachment site, and verb type, but the interaction was reliable only by participants [first pass: $F(1, 20) = 4.81, p < .05, F(2, 38) = 1.81, p > .10$]; total times: $F(1, 20) = 4.29, p = .05, F(2, 34) < 1.0, p > .5$]. Both measures revealed faster reading times for action-verb conditions than for psych/perception-verb conditions [first pass: $F(1, 20) = 6.06, p < .05, F(2, 31) = 6.25, p < .05$; total times: $F(1, 20) = 24.73, p < .01, F(2, 34) = 12.34, p < .01$]. In addition, the total reading times were faster for unambiguous conditions [$F(1, 20) = 14.66, p < .01, F(2, 34) = 55.30, p < .01$]. In contrast, there was no hint of the predicted interaction in either the probability of first-pass regressions or the regression path durations [$F_s < 1.0$], as can be seen in the lower halves of Figures 7 and 8. Both of these measures did produce the main effect of verb type, with fewer regressions/shorter durations in the action verb conditions [first-pass regressions: $F(1, 20) = 9.86, p < .01, F(2, 39) = 6.54, p < .05$; regression path durations: $F(1, 20) = 20.11, p < .01, F(2, 32) = 12.69, p < .01$] as well as an effect of attachment, with fewer regressions for VP-attached conditions [first-pass regressions: $F(1, 20) = 5.35, p < .05, F(2, 39) = 6.96, p < .05$; regression path durations: $F(1, 20) = 6.03, p < .05, F(2, 32) = 7.26, p < .05$]. In sum, the predicted interaction was reliably present only in the participants analysis for the first pass and total time measures.

Replication of Spivey-Knowlton and Sedivy (1995) verb-class effect on ambiguous stimuli. In this section, we consider only the ambiguous action and psych/perception verb conditions, which were summarized in Figure 7. The goal is to determine whether we have replicated the Spivey-Knowlton and Sedivy (1995) pattern: a VP-attachment advantage for action verbs and a NP-attachment advantage for psych/perception verbs, during the PP region. In the first-pass times, there appeared to be an interaction with the expected pattern at the PP. However, it was not even marginally reliable [$F(1, 20) = 2.36, F(2, 38) = 1.05, p > .10$]. The predicted interaction was found during the PP region of the

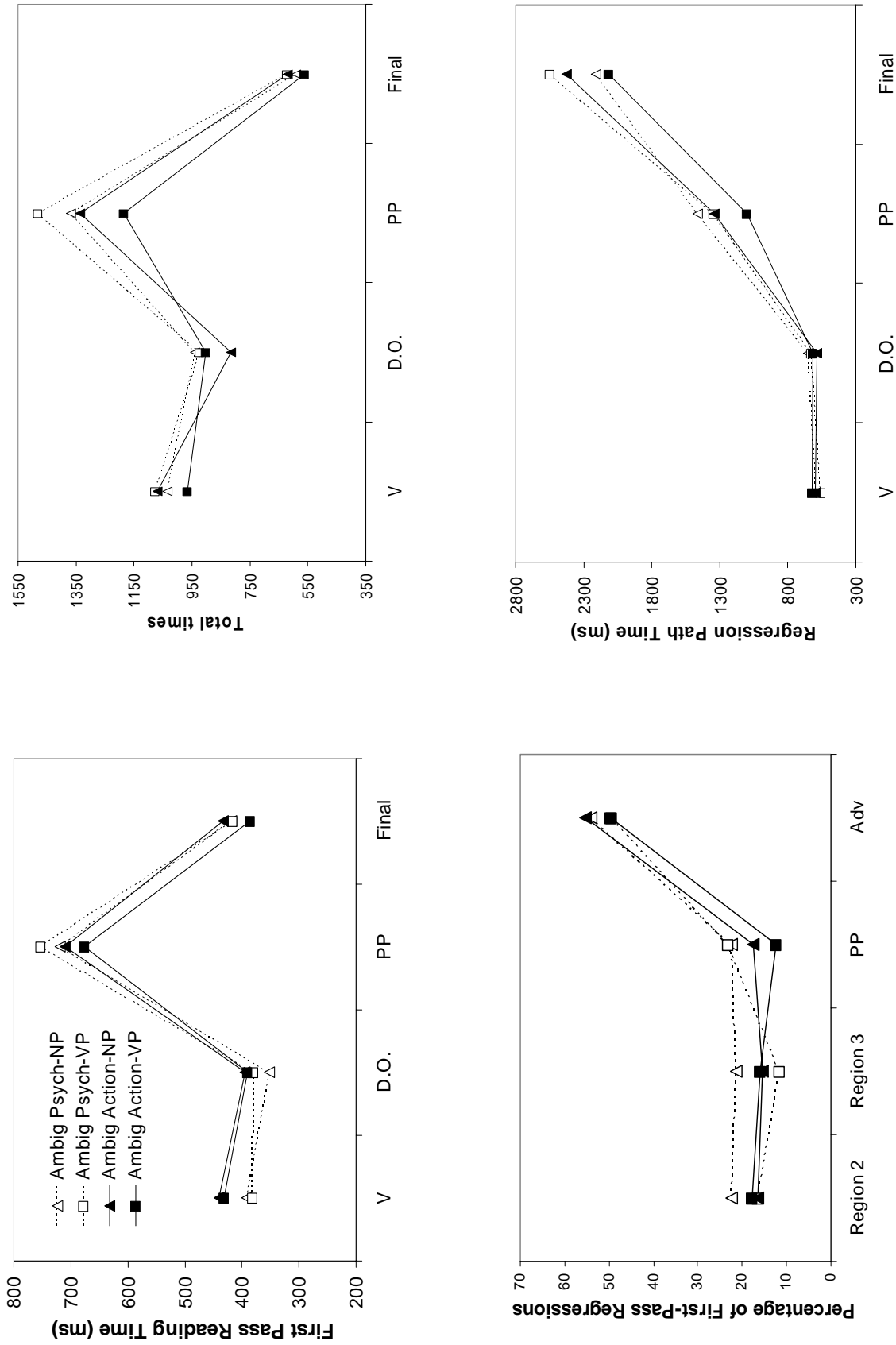
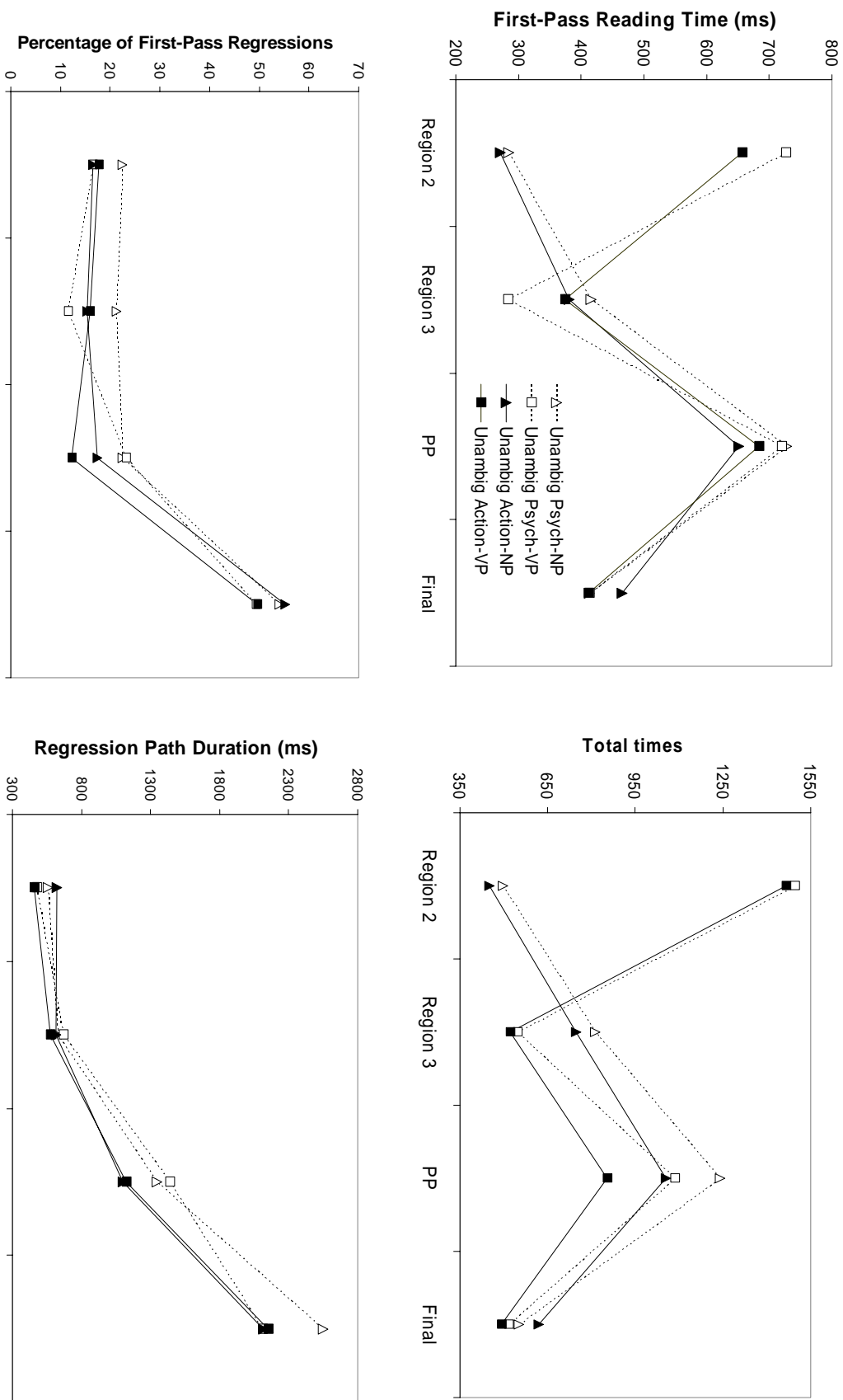


Figure 7. The data for the ambiguous conditions of the action-verb and psych/perception verb stimuli are summarized according to the four dependent measures of interest: first-pass reading time (upper left), total reading time (upper right), probability of a regression (lower left) and regression path duration (lower right). All durational measures are given in ms, but the time scale differs for each dependent measure.

Figure 8. The data for the unambiguous conditions of the action-verb and psych/perception-verb stimuli are summarized for each of the four dependent measures: first-pass reading time (upper left), total reading time (upper right), probability of a regression (lower left) and regression path duration (lower right). The time scale differs for each dependent measure.



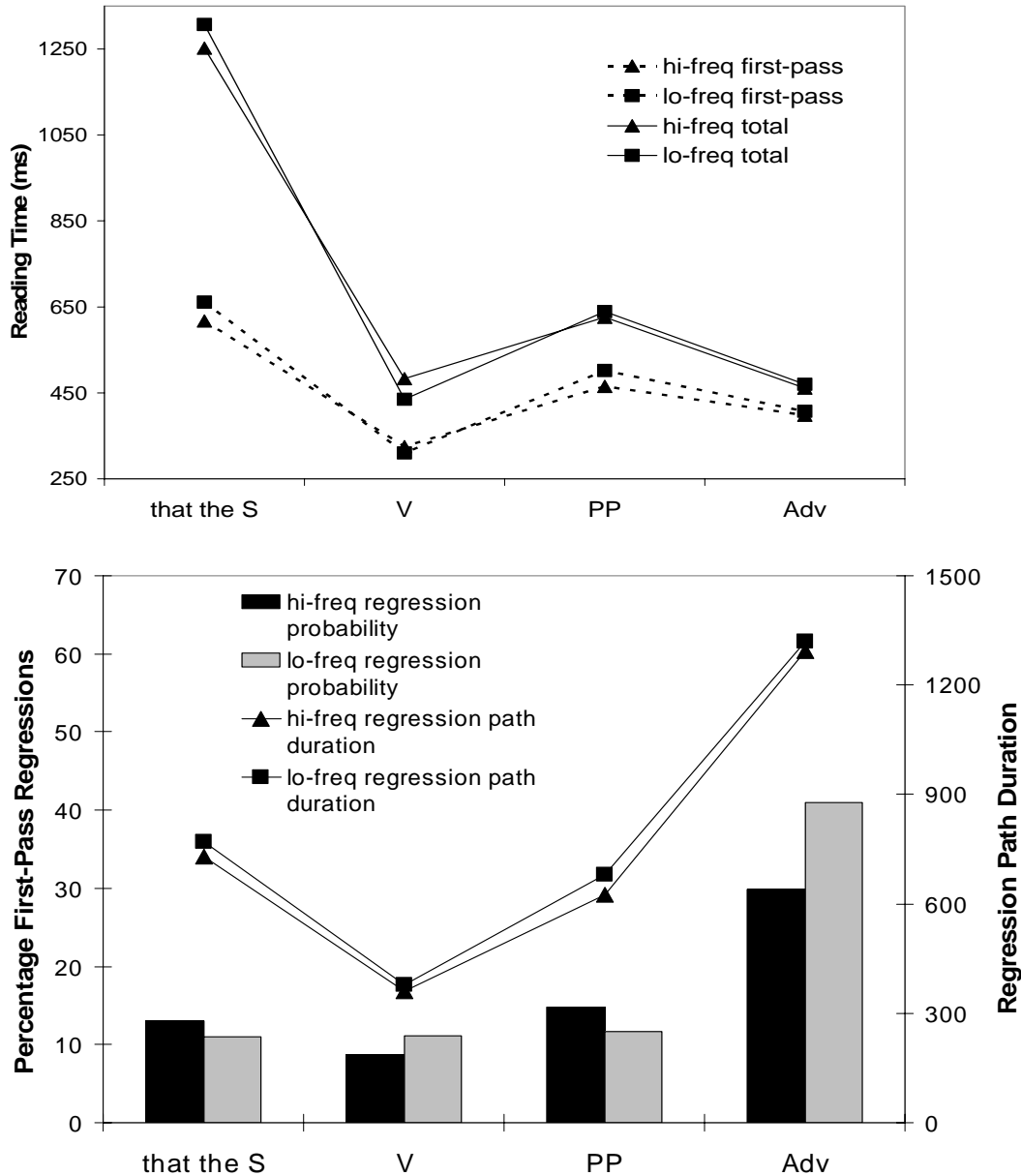


Figure 9. The first-pass and total reading time data for the two dative verb conditions are summarized in the upper portion of the figure. Note that the scale is different from that used for the action-verb and psych/perception-verb stimuli in Figures 7 and 8. The lower portion of the figure summarizes the probability of a first-pass regression and the regression path durations. The probabilities are mapped to the same scale as in Figures 7 and 8, but the scale for the regression path durations is different due to the much shorter durations in the final region.

total reading times, though only in the analysis by participants [$F(1, 20) = 8.09$, $F(1, 34) = 1.10$, $p > .10$]. There was no evidence of the predicted interaction in the probability of a first-pass regression or in the regression path durations during the PP region. However, the predicted interaction was observed in the final sentence region for the regression path duration measure [$F(1, 20) = 11.96$, $F(1, 40) = 8.08$, $p < .01$].

In sum, the Spivey-Knowlton and Sedivy (1995) pattern was not robustly replicated during the PP region. A non-

significant trend was observed in the first-pass reading times, and the interaction was found only in the participants' analysis of the total reading times. The only dependent measure that exhibited a fully reliable effect was the post-PP region of the regression path durations. Note that the regression path durations are substantially longer than the total reading times in this region, because there was a regressive eye movement out of the final region about half the time. The regression path durations for the final region include all fixations in previous regions following a regression until the readers' eyes

move to the right of the final region. Thus, this measure is fairly global.

Unambiguous versions of Spivey-Knowlton and Sedivy (1995) Stimuli. These data were summarized in Figure 8. As in Experiment 1, we expected to find no evidence of the Spivey-Knowlton and Sedivy (1995) verb class effect in the unambiguous action- and psych/perception-verb conditions. Although there was no evidence of the verb type by attachment interaction in the first-pass times, the action-verb conditions were faster than the psych/perception-verb conditions [$F1(1, 20) = 3.53, p < .10; F2(1, 39) = 4.68, p < .05$]. Because it is critical to the Argument Structure Hypothesis that the VP-attached action-verb condition not be faster than the VP-attached psych/perception-verb condition, planned comparisons ($\alpha = .05$) were carried out on those two conditions and no difference was found [$t's < 1.0$]. The verb type effect was also observed in the total reading times [$F1(1, 20) = 25.11, F2(1, 36) = 20.03, p < .01$], the probability of a first-pass regression [$F1(1, 20) = 8.20, F2(1, 38) = 7.89, p < .05$], and the regression path durations [$F1(1, 20) = 18.08, F2(1, 36) = 19.04, p < .05$]. However, none of these verb type effects interacted with attachment site during the PP region. There was an interaction between verb type and attachment site during the final region for the total reading times in the analysis by participants only [$F1(1, 20) = 4.77, p < .05; F2(1, 40) = 2.49, p > .10$].

Unambiguous Datives. These conditions were analyzed separately. The data for the four dependent measures are summarized in Figure 9. Because the dative PPs are arguments, we expected to find a lexical frequency effect at the PP for the first pass measures. Planned comparisons at the PP revealed the expected frequency effect only in the first pass reading times, and only in the items analysis [$t1(23) = 1.41, p > .10; F2(1, 14) = 18.13, p < .01$]. While this may appear to be weak evidence for the lexical frequency effect, it is bolstered by two other findings. First, a linear regression revealed that first-pass reading time was correlated with the likelihood of a dative PP in the sentence completions [$F2(1, 30) = 5.72, p < .05, r = -.40$]. Second, robust effects of lexical frequency were observed in the first fixations in the PP region, both in a planned comparison [$t1(23) = 2.52, p < .05; F2(1, 14) = 5.90, p < .05$] and a linear regression against the likelihood of a dative PP [$F2(1, 30) = 15.94, p < .01, r = -.59$]. This relationship is illustrated in Figure 10. The negative correlation indicates that the more likely a dative PP for a given verb, the shorter the first fixation on a dative PP following that verb.

Discussion

We replicated each of the primary findings from Experiment 1: the albeit weak verb-class by attachment-site interaction in the temporarily ambiguous Spivey-Knowlton and Sedivy (1995) stimuli, the absence of the interaction in the unambiguous versions of the Spivey-Knowlton and Sedivy (1995) stimuli, and the presence of lexical-frequency effects in the dative stimuli. In addition, there were differences in

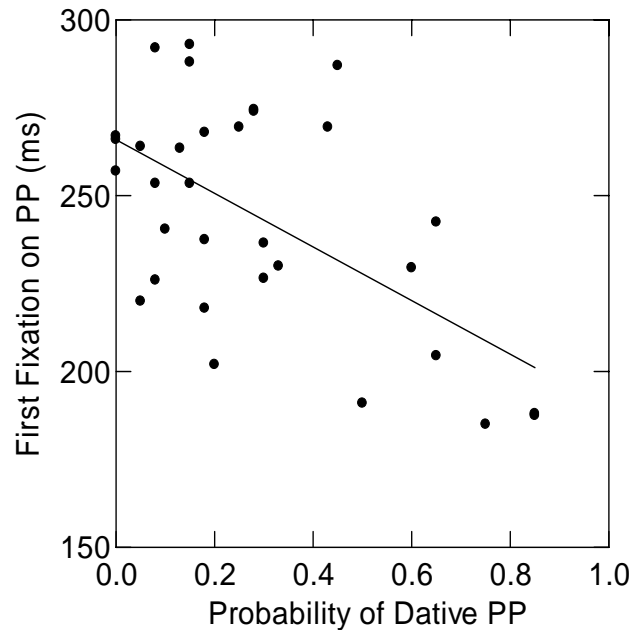


Figure 10. The scatterplot illustrates the correlation between the first fixations in the dative PPs and the probability of a dative PP in the sentence completions.

Table 4

Summary of late dependent measures from dative conditions

	Region		
	Verb	PP	Final
Probability of regression			
High frequency	9%	15%	30%
Low frequency	11%	12%	41%
Regression path duration (ms)			
High frequency	360	625	1,294
Low frequency	377	681	1,319
Total Reading Time (ms)			
High frequency	483	626	461
Low frequency	435	639	470

the timing of the verb-class effects for PP adjuncts and the lexical-frequency effects for PP arguments that directly support our claim that the two effects are evoked at different levels of syntactic analysis. The Spivey-Knowlton and Sedivy (1995) verb-class effects, which we believe to be pragmatically driven, were most robust in the later dependent measures, while the lexical-frequency effects for our dative-PP arguments were most robust in the earliest dependent measures.

General Discussion

Constraint-based lexicalist theories, together with the increased lexicalization of syntactic theories, have altered the way that many psycholinguists think about syntactic analysis during sentence comprehension. The focus has largely shifted away from phrase structure rules to syntactic knowledge that is accessed from the lexicon during word recognition and pieced together to generate sentence-level syntactic representations, as illustrated in Figure 1 above. With this shift, predictions about processing difficulty are linked to lexical frequency variables that determine the accessibility of the syntactic knowledge. This lexicalist account predicts the frequency effects that we found for dative arguments in both experiments: Integrating a recipient PP is more efficient following a verb that frequently occurs with such an argument compared to a verb that occurs less frequently with such an argument.

There are two primary contributions of the current paper. First, we have demonstrated that not all processing differences that are correlated with lexical frequency reflect a lexicalized mechanism for generating syntactic structure. Second, we have provided further evidence for the general distinction between generation and selection processes, along with some diagnostic tools for determining the different information sources brought to bear by these processes. In the current study we used these tools to determine the extent of the lexicalization of syntactic knowledge. The current results support the Argument Structure Hypothesis over the Full Lexical Representation Hypothesis. Our conclusions rest upon two distinctions that have not been clear in most papers advocating a constraint-based lexicalist approach. The first distinction is between knowledge that is used to generate structural representations and knowledge that is used to resolve ambiguities (Altmann & Steedman, 1988; Boland, 1997a; Lewis, 1993). The second distinction is between phrases that serve as arguments and those that serve as adjuncts.

The current results demonstrate that the generation of structure is influenced by bottom-up properties of the lexical items, including the relative frequencies of alternative argument structures. By hypothesis, adjunct sites are not lexically stored, and therefore, their relative frequencies do not contribute to the generation of modifier attachments—precisely the pattern observed here. In contrast to syntactic generation, ambiguity resolution depends upon a variety of other constraints, including pragmatic fit with the current context. This division of labor is a natural one, because pragmatic constraints are predicated on the interpretations of the structural alternatives and should therefore follow their generation. (Note that this is not the classic first-pass/reanalysis distinction in syntactic analysis in which only one structure is generated.)

The comparison of adjunct PP attachments, in syntactically ambiguous and unambiguous environments, reveal that the Spivey-Knowlton and Sedivy (1995) findings were not, in fact, a demonstration that specific adjunct attachment sites (i.e., a site for a *with*-PP) are encoded or indexed in the

lexical entry of the verb heading the VP, nor that the co-occurrence statistics are somehow facilitating structural integration of the PP into the verb phrase. Granted, it is always possible that a higher-frequency adjunct class (if one could be found) would pattern like the dative arguments. We have focused here on an adjunct class that has been reported to differ dramatically in frequency of occurrence across different sets of verbs, and for which the adjunct frequency has been claimed to be lexically encoded. Such claims are not unique to Spivey-Knowlton and Sedivy (1995). For instance, Snedecker and Trueswell (in press) used sentence completions of fragments like *Grover tickles/finds the teddy bear with...* to determine that *tickle* has an instrument bias and *find* has a bias toward occurring with modified direct objects. This lexical bias dimension was contrasted with a referential scene manipulation, which presumably implicates pragmatic knowledge. Snedecker and Trueswell found that children, in contrast to adults, relied exclusively on the lexical biases to guide syntactic ambiguity resolution. While we do not doubt the importance of the finding, the current data suggest caution in drawing the conclusion that their lexical bias variable reflects lexically encoded syntactic knowledge, or the relative accessibility of alternative argument structures.

These findings are consistent with other recent studies suggesting that adjuncts are not lexically specified (e.g. Boland & Boehm-Jenigan, 1998). In fact, we know of no empirical evidence suggesting that adjunct information is encoded on a lexical head. It is unlikely that such evidence will ever be found, given that we have already tested the strongest possible case in English: Instrumental *with*-PPs are among the most frequent of adjuncts, and some linguists have even suggested that they might be arguments (see discussion in Schutze & Gibson, 1999). Evidence that these PPs are not lexically represented is also evidence that they are adjuncts; linguistic theory maintains that arguments must be lexically represented as part of argument structure. This is not to say that no verbs take instruments as arguments. Some verbs may take instrument arguments, as argued by Koenig et al. (2003). It may even be the case that a few of the action verbs used by both Spivey-Knowlton and Sedivy (1995) and ourselves fall into that category. However, our results clearly indicate that, as a group, these verbs do *not* subcategorize for instrument PPs.

The pattern of results in our studies provides significant constraint on a broad range of theories concerning sentence processing architecture. We now consider the implications for two competition models (the constraint-based model of Spivey and Tanenhaus (1998) and the competitive attachment model of Stevenson (1995)), and a structure-driven Minimal Attachment model (Frazier, 1987; Frazier & Fodor, 1978). We choose these models because they are simple and clearly articulated instantiations of divergent viewpoints.

Consider first the predictions of the Spivey and Tanenhaus (1998) implemented constraint-based competition model. This model does not posit a clear architectural distinction between generation and selection, so it is interesting to explore how it might account for our results. The key is to characterize unambiguous structures as very biased ambiguous

structures where the constraints heavily favor one interpretation. The model could thereby account for the verb class by ambiguity interaction for the adjunct stimuli in the following way. Suppose that the difference in overall strength of the alternatives in the ambiguous conditions is actually fairly small. The ambiguity serves as a kind of nonlinear amplifier of these small differences. The closer together the overall strength of two possible interpretations, the bigger the effect that differences in supporting constraint strengths will have. If unambiguous conditions are in fact simply very heavily-biased ambiguous structures, there is very little time taken by the competition, and correspondingly very little variance introduced by differences in constraint strengths. Thus, one could posit a modest difference in adjunct attachment site strengths between the two verb classes, and a nonlinear competition mechanism might predict substantial effects of this difference in relatively equi-biased ambiguous constructions, but a near elimination of the difference in heavily biased or unambiguous constructions.

The problem with this account, however, is that there are significant verb frequency effects for argument PP attachments (the dative conditions) in unambiguous structures. Competition models cannot easily predict the existence of these effects while simultaneously predicting their absence in the adjunct conditions. Of course, it is possible that the size of the frequency effect in the dative conditions is small enough in the present experiments that the Spivey and Tanenhaus (1998) competition model or something similar could roughly fit the data. A model that could fit the dative data would necessarily predict some small effect in the adjunct conditions, but perhaps such differences could be observed if an experiment could be designed that was sensitive enough to detect them. However, the goal is not to develop a model that can handle these specific contrasts alone. Such a model must be able to account for the full range of lexical frequency effects. We suspect that there are other examples of lexical frequency effects in unambiguous constructions that are sizeable enough to rule this out as a general solution (e.g., the noun-verb homograph data of Boland, 1997a).

An alternative for a competition model is to assume that there is a separate lexically driven generation process that provides weighted structures that enter into the competition. In fact, Spivey and Tanenhaus (1998) explicitly claim that a separate generation process is necessary for the competition model to be complete. What we are suggesting here is that the present data provide additional motivation for this distinction, as well as constraints on the content of the generating lexical information, in line with the Argument Structure Hypothesis.

We also considered a competition model that incorporates different competitive behavior for arguments and adjuncts: the competitive attachment model of Stevenson (1995). However, implementing an argument/adjunct distinction is insufficient to account for all of our findings. In Stevenson's model, the competitive activation processes that focus activation onto a preferred argument attachment site exhibit "winner-take-all" behavior so that only a single argument node is activated. Adjunct sites, by contrast, employ

a much less competitive activation function. This difference in competitive behavior yields an argument preference for phrases that are temporarily ambiguous between attachment as an argument and attachment as an adjunct, even though argument and adjunct attachments have equal *a priori* activation levels. In adjunct-adjunct competitions such as those in our ambiguous adjunct stimuli (*I saw the man with the telescope*), recency supports VP attachment of the PP, but this can be easily overridden by lexical or pragmatic preferences. Thus, the model can account for the original Spivey-Knowlton and Sedivy (1995) result, regardless of whether the cause is lexical frequency or pragmatics. In contrast, it is difficult to see how Stevenson's model could predict the lexical frequency effects for our unambiguous arguments, given that the model requires all arguments and adjuncts to have equivalent *a priori* activation levels. Once again, a distinction between generation and selection is necessary to account for the results in the unambiguous conditions.

Finally, consider the implications of our results for a structure-driven Minimal Attachment approach. To draw out these implications, it is useful to return to one of the original descriptions of Minimal Attachment, in Frazier and Fodor (1978), although our analysis holds for later versions of this approach as well. Frazier and Fodor (1978) posited a generation mechanism not unlike the one we propose here. In this model, Minimal Attachment is assumed to emerge from a race between alternative syntactic structures generated in parallel. The winner of the race is the most rapidly-generated structure, where speed of generation is determined by structural complexity (number of syntactic nodes introduced). Minimal Attachment thus combines generation and selection into a single stage: selection is an emergent by-product of race-based generation.

Under the standard assumption that only major category information drives the initial structure generation, the model must account for the verb-class by ambiguity interaction in the adjunct stimuli by assuming (as we do above) that the verb-class ambiguity effect in the ambiguous conditions is a post-generation plausibility effect. But the two accounts diverge significantly in the following way. Our generation-selection account assumes the locus of the effect is syntactic selection and reanalysis. Under the Minimal Attachment account, however, the locus of the effect *cannot* be reanalysis, because the VP-attachment will be generated first regardless of verb class, hence no reanalysis is required. Minimal Attachment model must therefore assume that the locus of the effect is interpretation: adjuncts attached to action verbs are faster to interpret than adjuncts attached to psych/perception verbs.

Considering only the ambiguous conditions, the two accounts are theoretically different but empirically indistinguishable. However, if the locus of the effect in the Minimal Attachment account is interpretation, then the same verb-class effect should arise in the unambiguous conditions as well. But it does not—this is the verb class by ambiguity interaction. Minimal Attachment alone cannot account for this pattern. Construal (Frazier & Clifton, 1996) also fails to account for the interaction, because all of the PPs consid-

ered here would initially be treated as primary phrases and therefore subject to the standard constraints of Minimal Attachment and Late Closure.

This comparison of the predictions of the competition models and Minimal Attachment models highlights a key constraining fact about the data: there must be some way that the processing mechanism gives rise to the verb class effect in ambiguous constructions, but not in unambiguous constructions. We have offered above two possible models that have this property: an architecture that distinguishes generation and selection (with plausibility constraints affecting selection and lexical frequency affecting generation) and a non-linear competition mechanism that magnifies frequency effects in closely-weighted ambiguous constructions, while compressing them in heavily-biased (nearly unambiguous) constructions. At the same time, we raised concern that the competition models will not fare well when considering a wider range of lexical-frequency effects.

Finally, although we have argued that global syntactic knowledge is used to analyze adjuncts, we do not wish to dispense with the lexicalized parsing mechanism that is central to some constraint-based lexicalist accounts. The Argument Structure Hypothesis is a variant of the constraint-based lexicalist approach, in which detailed lexical information is exploited to build the structures that express predicate-argument relations. This approach differs from extreme lexicalist positions in maintaining that global (non-lexicalized) syntactic rules are necessary to fill in some structural details that are not encoded on the lexical items. Based on evidence presented here and elsewhere, it is clear that both lexical and non-lexical cognitive mechanisms underlie syntactic analysis.

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Appendix Stimuli for Experiments 1 and 2

The stimuli from Experiments 1 and 2 are presented below. The stimuli using the psych/perception verbs are listed first, followed by the stimuli using the action verbs. In both cases, the conditions are in the following order: (a) NP-attachment, ambiguous; (b) VP-attachment, ambiguous; (c) NP attachment, unambiguous; (d) VP-attachment, unambiguous. The Dative stimuli are presented last, with the high frequency verb and low frequency verb, respectively, separated by slashes.

Psych/Perception verbs

The first ten are taken directly from Spivey-Knowlton and Sedivy (1995), with minor modifications. Items 11-16 have new verbs (w/o particles), but otherwise incorporate the Spivey-Knowlton and Sedivy (1995) materials as much as possible.

1. (a) The executive sought a promotion with a salary increase last year but he was fired instead.
(b) The executive sought a promotion with bold determination last year but he was fired instead.
(c) The executive's goal was a promotion with a salary increase last year but he was fired instead.
(d) The promotion that the executive sought with bold determination last year did not come to pass.
2. (a) The woman expected a bus with air conditioning this morning but she was at the wrong stop.
(b) The woman expected a bus with much anticipation this morning but she was at the wrong stop.
(c) The woman's reservation was for a bus with air conditioning this morning but she was at the wrong stop.
(d) The bus that the woman expected with much anticipation this morning finally arrived about an hour late.
3. (a) The spy saw a cop with two revolvers Wednesday night but the cop didn't see him.
(b) The spy saw a cop with little effort Wednesday night but the cop didn't see him.
(c) The spy's main worry was a cop with two revolvers Wednesday night but the cop didn't see him.
(d) The cop that the spy saw with little effort Wednesday night didn't know he was being watched.
4. (a) The bank manager knew a combination with twelve digits every day but it didn't open the safe.
(b) The bank manager knew a combination with total certainty every day but it didn't open the safe.
(c) The bank manager's first try was a combination with twelve digits every day but it didn't open the safe.
(d) The combination that the bank manager knew with total certainty every day failed to open the safe.
5. (a) The teaching assistant despised a student with a bad attitude all year but graded everyone fairly.
(b) The teaching assistant despised a student with no clear reason all year but she graded everyone fairly.
(c) The teacher's biggest concern was a student with a bad attitude all year but she graded him fairly.
(d) The student that the teaching assistant despised with no clear reason all year was graded fairly by her.
6. (a) The musician heard a performance with thirty violins Tuesday night and he loved it all.
(b) The musician heard a performance with some difficulty Tuesday night and he loved it all.
(c) The musician's first piece was a performance with thirty violins Tuesday night and we loved it all.
(d) The performance that the musician heard with some difficulty Tuesday night had at least thirty violins.
7. (a) The supervisor demanded a report with sales figures sometime today so we all worked on it.
(b) The supervisor demanded a report with fierce insistence sometime today so we all worked on it.
(c) The supervisor's goal was a report with sales figures sometime today so we all worked on it.
(d) A report that the supervisor demanded with fierce insistence sometime today kept us all working late.
8. (a) The child tasted a chocolate with chopped almonds this afternoon and he quickly ate it all.
(b) The child tasted a chocolate with secret delight this afternoon and he quickly ate it all.
(c) The child's treat was a chocolate with chopped almonds this afternoon and he quickly ate it all.
(d) The chocolate that the child tasted with secret delight this afternoon was full of chopped almonds.
9. (a) The young girl loved a man with a nice mustache once again but she feared marriage.
(b) The young girl loved a man with all her heart once again but she feared marriage.
(c) The young girl's romantic interest was a man with a nice mustache once again but she feared marriage.

- (d) The man that the young girl loved with all her heart once again had a nice mustache.
10. (a) The designer smelled a perfume with a floral scent yesterday morning and she pronounced it divine.
 (b) The designer smelled a perfume with a quick sniff yesterday morning and she pronounced it divine.
 (c) The designer's project was a perfume with a floral scent yesterday morning and she sniffed it often.
 (d) The perfume that the designer smelled with a quick sniff yesterday morning had a strong floral scent.
11. (a) The saleswoman acknowledged the customer with ripped trousers Monday evening and then walked away.
 (b) The saleswoman acknowledged the customer with a polite nod Monday evening and then walked away.
 (c) The saleswoman's concern was a customer with ripped trousers Monday evening but he walked away.
 (d) A customer that the saleswoman acknowledged with a polite nod Monday evening had already walked away.
12. (a) The contestant wanted a prize with a million dollars this year but she left empty-handed.
 (b) The contestant wanted a prize with her entire being this year but left she empty-handed.
 (c) The contestant's dream was a prize with a million dollars this year but she left empty-handed.
 (d) The prize that the contestant wanted with her entire being this year was a million dollars.
13. (a) The troubled woman noticed a fellow with a kind face Saturday afternoon and he helped her.
 (b) The troubled woman noticed a fellow with a quick glance Saturday afternoon and he helped her.
 (c) The troubled woman's date was a fellow with a kind face Saturday afternoon and he helped her.
 (d) The fellow that the woman noticed with a quick glance Saturday afternoon tried hard to help her.
14. (a) The old man understood an opera with three acts last week and he remembered it fondly.
 (b) The old man understood an opera with great difficulty last week but he remembered it fondly.
 (c) The old man's special outing was an opera with three acts last week and he remembered it fondly.
 (d) The opera that the old man understood with great difficulty last week was his favorite performance.
15. (a) The sailor finally spotted a ship with familiar markings Sunday evening but he saw pirates on deck.
 (b) The sailor finally spotted a ship with great effort Sunday evening but he saw pirates on deck.
 (c) The sailor's last hope was a ship with familiar markings Sunday evening but it had pirates on deck.
 (d) The ship that the sailor spotted with great effort Sunday evening had several pirates on deck.
16. (a) The scholar coveted an award with great prestige each year and he finally won it.
 (b) The scholar coveted an award with great longing each year and he finally won it.
 (c) The scholar's lasting dream was an award with great prestige each year and he finally won it.
 (d) The award that the scholar coveted with great longing each year was given to someone else.
17. (a) The scientist detected an organism with an orange glow last month but later lost his notes about it.
 (b) The scientist detected an organism with a microscope last month but later lost his notes about it.
 (c) The scientist's greatest discovery was an organism with an orange glow last month but she lost his notes about it.
 (d) The organism that the scientist detected with a microscope last month had an interesting orange glow.
18. (a) The surgeon felt a lump with an unusual shape this morning and he removed it completely.
 (b) The surgeon felt a lump with a special probe this morning and he removed it completely.
 (c) The surgeon's main concern was a lump with an unusual shape this morning but he removed it completely.
 (d) The lump that the surgeon felt with a special probe this morning had an unusual shape.
19. (a) The psychic sensed a presence with dangerous motives last night and she tried to contact it.
 (b) The psychic sensed a presence with her crystal ball last night and she tried to contact it.
 (c) The psychic's biggest fear was a presence with dangerous motives last night but she tried to contact it.
 (d) The presence that the psychic sensed with her crystal ball last night had very dangerous motives.

20. (a) The hungry child glimpsed a sandwich with tuna salad this evening and he managed to steal it.
 (b) The hungry child glimpsed a sandwich with a quick peek this evening and he managed to steal it.
 (c) The hungry child's only thought was a sandwich with tuna salad this evening and he managed to steal it.
 (d) The sandwich that the hungry child glimpsed with a quick peek this evening was a tuna salad on rye.
21. (a) The biologist observed a whale with a damaged tail this month and she collected more data on it.
 (b) The biologist observed a whale with an underwater scope this month and she collected more data on it.
 (c) The biologist's object of study was a whale with a damaged tail this month and she collected much data on it.
 (d) The whale that the biologist observed with an underwater scope this month had a badly damaged tail.
22. (a) The man overheard a woman with a raspy voice earlier today and he looked around for her.
 (b) The man overheard a woman with his hearing aid earlier today and he looked around for her.
 (c) The man's temporary assistant was a woman with a raspy voice this morning and he looked around for her.
 (d) The woman that the man overheard with his hearing aid this morning was a new temporary assistant.
23. (a) The editor scanned a newspaper with a shocking headline yesterday morning but didn't make a copy.
 (b) The editor scanned a newspaper with a trained eye yesterday morning but didn't make a copy.
 (c) The editor's goal was a newspaper with a shocking headline yesterday morning but he didn't succeed.
 (d) The newspaper that the editor scanned with a trained eye yesterday morning had a shocking headline.
24. (a) The professor examined a thesis with a novel claim this semester but he didn't like it.
 (b) The professor examined a thesis with some interest this semester but he didn't like it.
 (c) The professor had a thesis with a novel claim this semester but he didn't like it.
 (d) The thesis that the professor examined with some interest this semester had a novel claim.

Action verbs

Adapted from Altmann & Steedman(1988).

1. (a) The mechanic changed a tire with a faulty valve this morning but it took a while.
 (b) The mechanic changed a tire with a monkey wrench this morning but it took a while.
 (c) The car's problem was a tire with a faulty valve this morning but the mechanic fixed it.
 (d) The tire that the mechanic changed with a monkey wrench this morning had a faulty valve on it.
2. (a) The teacher beat a boy with a bad haircut yesterday morning but he didn't cry.
 (b) The teacher beat a boy with a bamboo cane yesterday morning but he didn't cry.
 (c) The teacher's scapegoat was a boy with a bad haircut yesterday morning but he didn't complain.
 (d) The boy that the teacher beat with a bamboo cane yesterday morning was the best student.
3. (a) The DJ played a record with a noisy crackle Wednesday night and it sounded terrible.
 (b) The DJ played a record with an expensive turntable Wednesday night and it sounded terrible.
 (c) The DJ's first song was a record with a noisy crackle Wednesday night and it sounded terrible.
 (d) The record that the DJ played with an expensive turntable Wednesday night sounded really terrible.
4. (a) The artist accidentally bumped a tray with new oil paints Tuesday night and he swore loudly.
 (b) The artist accidentally bumped a tray with his elbow Tuesday night and he swore loudly.
 (c) The artist's most useful tool was a tray with new oil paints Tuesday night but he bumped it accidentally.
 (d) The tray that the artist accidentally bumped with his elbow Tuesday night was full of paint.
5. (a) The convict suddenly attacked a guard with a noticeable limp earlier today before he ran away.
 (b) The convict suddenly attacked a guard with homemade weapons earlier today before ran away.
 (c) The convict's only obstacle was a guard with a limp earlier today and he outran him.
 (d) The guard that the convict attacked with homemade weapons earlier today was limping badly later.

6. (a) The janitor wiped a window with dirty fingerprints this afternoon while singing quietly to himself.
 (b) The janitor wiped a window with a clean cloth this afternoon while singing quietly to himself.
 (c) The janitor's next job was a window with dirty fingerprints this afternoon and he cleaned it quickly.
 (d) The window that the janitor wiped with a clean cloth this afternoon had dirty fingerprints on it.
7. (a) The workman cut through a pipe with rusty holes Monday evening before fitting a new one.
 (b) The workman cut through a pipe with a special saw Monday evening before fitting a new one.
 (c) The workman's problem was a pipe with rusty holes Monday evening but he to cut through it.
 (d) The pipe that the workman cut through with a special saw Monday evening had rusty holes in it.
8. (a) The monkey ate a banana with a rotten peel Saturday afternoon much to everyone's surprise.
 (b) The monkey ate a banana with some silverware Saturday afternoon much to everyone's surprise.
 (c) The monkey's snack was a banana with rotten peel Saturday afternoon but he ate it anyway.
 (d) The banana that the monkey ate with some silverware Saturday afternoon had a rotten peel.
9. (a) The caretaker repaired a door with a crack yesterday morning and then took a break.
 (b) The caretaker repaired a door with several nails yesterday morning and then took a break.
 (c) The caretaker's last job was a door with a crack yesterday morning and he repaired it quickly.
 (d) The door that the caretaker repaired with several nails yesterday morning had a crack in it.
10. (a) The skinhead angrily assaulted a cop with a big scar Sunday evening and then took off.
 (b) The skinhead angrily assaulted a cop with an iron bar Sunday evening and then took off.
 (c) The skinhead's target was a cop with a big scar Sunday evening and he assaulted him.
 (d) The cop that the skinhead angrily assaulted with an iron bar Sunday evening had a big scar.
11. (a) The dressmaker cut some material with navy pinstripes this morning and then she had lunch.
 (b) The dressmaker cut some material with large scissors this morning and then she had lunch.
 (c) The dressmaker's choice was some material with navy pinstripes this morning but she settled for plaid.
 (d) The material that the dressmaker cut with large scissors this morning had navy pinstripes on it.
12. (a) The fireman damaged a wall with beautiful paneling last night but got everyone out safely.
 (b) The fireman damaged a wall with his ladder last night but got everyone out safely.
 (c) The fireman's only barrier was a wall with beautiful paneling last night so he broke it down.
 (d) The wall that the fireman damaged with his ladder last night had beautiful paneling on it.
13. (a) The chemist heated a solution with yellow crystals this evening but the gas went out.
 (b) The chemist heated a solution with a bunsen burner this evening but the gas went out.
 (c) The chemist's goal was a solution with yellow crystals this evening but he couldn't manage it.
 (d) The solution that the chemist heated with a bunsen burner this evening had yellow crystals in it.
14. (a) The drunk smashed a window with stained glass once again then he staggered off laughing.
 (b) The drunk smashed a window with an empty bottle once again then he staggered off laughing.
 (c) The drunk's target was a window with stained glass once again and he smashed it laughing.
 (d) The window that the drunk smashed with an empty bottle once again had stained glass in it.
15. (a) The vet tranquilized a lion with a heavy mane last month and then examined it.
 (b) The vet tranquilized a lion with a harmless drug last month and then examined it.
 (c) The vet's worst patient was a lion with a heavy mane last month so he tranquilized it.
 (d) The lion that the vet tranquilized with a harmless drug last month had a heavy mane.
16. (a) The tribesman killed a tiger with dangerous teeth each year and carried it home.
 (b) The tribesman killed a tiger with a ceremonial spear each year and carried it home.
 (c) The tribesman's prey was a tiger with dangerous teeth each year and he carried a spear.
 (d) The tigers that the tribesman killed with a ceremonial spear each year had very dangerous teeth.
17. (a) The man demolished a house with a fountain this month but it wasn't the right one.

- (b) The man demolished a house with a bulldozer this month but it wasn't the right one.
- (c) The man's demolition target was a house with a fountain this month but the bulldozer couldn't destroy it.
- (d) The house that the man demolished with a bulldozer this month was at the wrong address.
18. (a) The restorer stripped a cabinet with brass hinges last year and then he waxed it.
- (b) The restorer stripped a cabinet with paint remover last year and then he waxed it.
- (c) The restorer's hardest project was a cabinet with brass hinges last year and he stripped it carefully.
- (d) The cabinet that the restorer stripped with paint remover last year had brass hinges on it.
19. (a) The secretary typed a report with complex diagrams Thursday morning and then faxed it to headquarters.
- (b) The secretary typed a report with a word processor Thursday morning and then faxed it to headquarters.
- (c) The secretary's task was a report with complex diagrams Thursday morning so she started the word processor.
- (d) The report that the secretary typed with a word processor Thursday morning had very complex diagrams in it.
20. (a) The burglar opened a door with a damaged lock this evening and then quickly slipped inside.
- (b) The burglar opened a door with a credit card this evening and then quickly slipped inside.
- (c) The burglar's only hindrance was a door with a damaged lock this evening so he quickly slipped inside.
- (d) The door that the burglar opened with a credit card this evening had a faulty lock anyway.
21. (a) The housekeeper cleaned a corridor with some plants every day and then lit a cigarette.
- (b) The housekeeper cleaned a corridor with a broom every day and then lit a cigarette.
- (c) The housekeeper's easiest chore was a corridor with some plants every day so she looked for a broom.
- (d) The corridor that the housekeeper cleaned with a broom every day had beautiful plants in it.
22. (a) The woman repaired a sock with a tiny hole last week but she hurt her finger.
- (b) The woman repaired a sock with a needle last week but she hurt her finger.
- (c) The woman had a sock with a tiny hole last week so she repaired it carefully.
- (d) The sock that the woman repaired with a needle last week had several holes in it.
23. (a) The boy broke a toy police car with a flashing light this morning and ran home crying.
- (b) The boy broke a toy police car with a shovel this morning and ran home crying.
- (c) The boy had a toy police car with a flashing light this morning but he broke it.
- (d) The toy police car that the boy broke with a shovel this morning had a flashing light.
24. (a) The homeowner painted a door with a small window this weekend and then he tidied up.
- (b) The homeowner painted a door with borrowed equipment this weekend and then he tidied up.
- (c) The homeowner's project was a door with a small window this weekend and he painted it easily.
- (d) The door that the homeowner painted with borrowed equipment this weekend was in the living room.

Dative verbs

The high and low frequency verbs are separated by a slash. The first verb is more frequently used with an indirect object than the second verb.

1. The chores that the parents delegated/suggested to their kids last week were very easy to accomplish.
2. The woman that the minister introduced/referred to his doctor Thursday morning was shy and quite nervous.
3. The suspect that the witness described/mentioned to the police Friday evening was taller than they had anticipated.
4. The plaque that the committee dedicated/awarded to the hero last year was engraved and ready to hang.
5. The letter that the teenager forwarded/passed to her boyfriend this afternoon was short and somewhat rude.
6. The procedure that the chemist explained/suggested to her colleagues this semester was quite complicated to carry out.
7. The uniform that the coach recommended/kicked to the athlete this morning was expensive and covered in logos.
8. The necklace that the girl lent/took to her sister last month was covered with sparkling diamonds.
9. The ice cream that the man brought/fed to his children Sunday afternoon was chocolate chip and butter pecan.

10. The ball that the baseball player handed/hit to his teammate earlier today was brand new and unscuffed.
11. The rifle that the soldier gave/left to his friend this year was from the Gulf War.
12. The item that the man sent/returned to the shop this Wednesday was damaged beyond repair.
13. The lyrics that the secretary mailed/sang to her mother Tuesday night were sentimental and quite personal.
14. The tuxedo that the tailor showed/sold to the groom last weekend had extra long sleeves and pantlegs.
15. The carrots that the zookeeper offered/slid to the bears each morning were scrubbed but not peeled.
16. The chapters that the teacher assigned/read to the class every Friday were from the required textbook.