Journal of Experimental Psychology:
Learning, Memory, and Cognition
1993, Vol. 19, No. 3, 528–553

0278-7393/93/$3.00

Verb-Specific Constraints in Sentence Processing: Separating Effects of Lexical Preference From Garden-Paths

John C. Trueswell, Michael K. Tanenhaus, and Christopher Kello

Immediate effects of verb-specific syntactic (subcategorization) information were found in a cross-modal naming experiment, a self-paced reading experiment, and an experiment in which eye movements were monitored. In the reading studies, syntactic misanalysis effects in sentence complements (e.g., "The student forgot the solution was. . .") occurred at the verb in the complement (e.g., *was*) for matrix verbs typically used with noun phrase complements but not for verbs typically used with sentence complements. In addition, a complementizer effect for sentence-complement-biased verbs was not due to syntactic misanalysis but was correlated with how strongly a particular verb prefers to be followed by the complementizer *that*. The results support models that make immediate use of lexically specific constraints, especially constraint-based models, but are problematic for lexical filtering models.

Many aspects of language comprehension take place rapidly, with readers and listeners making commitments to at least partial interpretations soon after receiving linguistic input (e.g., Altmann & Steedman, 1988; Crain & Steedman, 1985; Frazier, 1989; Frazier & Fodor, 1978; Marslen-Wilson & Tyler, 1987; Tyler, 1989). The on-line nature of comprehension has important consequences for syntactic processing (parsing). Immediate interpretation requires some local syntactic commitments even though sentences often contain temporary ambiguities. As a result, readers and listeners will occasionally make incorrect commitments that will require revision when an ambiguity is resolved at a later point in processing. The frequency of syntactic misanalysis or *garden-pathing* will depend on the types of commitments made by the system and the information used to determine these commitments. A system that makes complete syntactic commitments using only a restricted domain of syntactically relevant information will necessarily make more mistakes than a system making only partial commitments using a wider range of constraining information.

Individual words are one of the richest sources of syntactically relevant information. Perhaps the most important class of lexically specific constraints are those associated with verbs. Verbs provide both semantic and syntactic constraints on the kinds of complements or *arguments* with which they can occur. If immediately accessed and used, this information would be useful in ambiguity resolution. It could also be used to coordinate many of the different sources of linguistic and nonlinguistic knowledge that need to be integrated during on-line comprehension (Marslen-Wilson, Brown, & Tyler, 1988; Tanenhaus, Garnsey, & Boland, 1991; Tanenhaus & Carlson, 1989; Tanenhaus, Carlson, & Trueswell, 1989).

This article focuses on verb-specific syntactic constraints. Following Chomsky (1965), we refer to lexically specific information about potential syntactic complements as subcategorization information. Verb subcategorization information is particularly informative in languages like English in which a verb typically precedes most of its complements. In some cases, the syntactic analysis of an otherwise ambiguous word or phrase can be disambiguated by the subcategorization properties of the preceding verb, as Example 1 illustrates.

a. The doctor visited the child . . . . (Example 1)
b. The doctor insisted the child . . . .

In Example 1a the noun phrase "the child" is a noun phrase complement (i.e., the object of the verb), whereas in 1b the same phrase is the subject of a sentence complement (e.g., ". . . the child needed braces"). *Visited* permits a noun phrase complement but not a sentence complement, whereas just the opposite is true for *insisted.*

Verbs often permit several different types of complements. For example, both the verbs *remember* and *claim* permit either a noun phrase complement or a sentence complement.

John C. Trueswell, Michael K. Tanenhaus, and Christopher Kello (now at Department of Psychology, University of California, Santa Cruz), Department of Psychology, University of Rochester.

This work was partially supported by National Institutes of Health (NIH) Grant HD 27206 and by NIH Grant EY 01319 to the Center for Visual Science.

We are grateful to Susan Garnsey for providing us with preliminary versions of her completion norms as well as for helpful suggestions and comments on the article. The completion norms reported here were collected by Christopher Kello as part of his senior honors thesis in cognitive science. Experiment 1 is an extension of work that Kello conducted for his thesis. This article benefited from suggestions by the reviewers, Chuck Clifton, Fernanda Ferreira, Maryellen MacDonald, and Chuck Perfetti. Some of this work was reported at the November 1991 meeting of the Psychonomics Society, San Francisco.

Correspondence concerning this article should be addressed to John C. Trueswell, Department of Psychology, University of Rochester, Rochester, New York 14627. Electronic mail may be sent to trueswel@psych.rochester.edu.

a. The doctor remembered the idea .... (Example 2)
b. The doctor suspected the idea ....

As a result, in 2a and 2b the relationship between the noun phrase "the idea" and the preceding verb is ambiguous. Nonetheless, the verb still provides potentially useful information. *Remembered* is more frequently used with a noun phrase complement, whereas *suspected* is more frequently used with a sentence complement. As Ford, Bresnan, and Kaplan (1982) have suggested, frequency information like this would be extremely useful in ambiguity resolution. Indeed, in 2a there seems to be a strong preference to take "the idea" as the object of the verb, whereas in 2b the preference is for "the idea" to be the subject of a sentence complement.

When verb subcategorization information is accessed and used has important implications for parsing. A parser that takes subcategorization information into account in making initial syntactic commitments will necessarily make fewer mistakes than a parser that uses subcategorization information as a filter to evaluate commitments made without the use of verb-specific information (Mitchell, 1987). How subcategorization information is used also has implications for different classes of parsing models, which can be highlighted by contrasting two currently influential approaches to ambiguity resolution: *constraint-based models* and *two-stage models*.

Constraint-based models treat ambiguity resolution as a continuous constraint–satisfaction process (McClelland, St. John, & Taraban, 1988; Taraban & McClelland, 1990). In current structurally driven variants, syntactically relevant information provides evidence about partially activated alternatives (MacDonald, 1992; Pearlmutter & MacDonald, 1992; Spivey-Knowlton, Trueswell, & Tanenhaus, 1992; Trueswell, Tanenhaus, & Garnsey, 1992). Because verbs are a source of strong local constraints, one would expect to see immediate effects of subcategorization as well as effects of category-based configurational constraints. The relative contributions of these sources of information will depend on their reliability. In addition to subcategorization effects, there should also be effects of lexical co-occurrence patterns, such as the frequency with which a verb occurs with a particular word in a given structure.

Two-stage models assume that parsing proceeds serially, with only one structure under active consideration. During the first stage, a restricted domain of syntactically relevant information is used to posit an initial structure. This structure is then evaluated and, if necessary, revised. The evaluation and revision stage can make use of information that is not used in initial structure building. The two-stage model that is currently most influential in the literature is the garden-path model, originally proposed by Frazier and Rayner (1982). In this model, initial structure building is guided by a small set of maximally general attachment principles. For example, one such principle, minimal attachment, states that at points of ambiguity, the parser prefers to build the structure with the fewest number of nodes consistent with the grammar of the language. Garden-paths occur whenever the structure that conforms to the relevant attachment principles turns out to be incorrect.

Within the architecture of the garden-path model, lexically specific information is most naturally used in the revision stage. As Frazier (1987, 1989) has argued, using subcategorization information in initial structure building would limit the scope and generality of the attachment principles and require many attachment decisions to be delayed. Thus, most proponents of the garden-path model have argued for lexical-filtering approaches (Clifton, Speer, & Abney, 1991; Ferreira & Henderson, 1990, 1991; Frazier, 1987; Frazier & Clifton, 1989). Early use of subcategorization information is not, however, incompatible with a two-stage serial approach to parsing. For example, Ford et al. (1982) combined the immediate use of lexically specific information with a different set of attachment principles than those argued for by Frazier and colleagues.

There is a growing body of psycholinguistic literature focusing on the use of verb-based information in parsing. Many of these studies find evidence for the early use of both the semantic and the syntactic aspects of verb argument structure. (For a recent review see Boland & Tanenhaus, 1991.) However, two recent studies report results that would seem to provide striking support for lexical filtering (Ferreira & Henderson, 1990; Mitchell, 1987). In these studies, readers seemed to be garden-pathed because they initially parsed a noun phrase as the object of a verb that does not permit a noun phrase complement.

Mitchell (1987) used sentences such as Examples 3a and 3b in a self-paced reading study. The sentences were presented in two segments; the slashes mark the segmentation.

a. After the child visited the doctor/prescribed a course of injections. (Example 3)
b. After the child sneezed the doctor/prescribed a course of injections.

In Mitchell's study, the first segment in 3a was read more rapidly than the first segment in 3b, whereas the opposite pattern obtained for the second segment. Mitchell argued that the results from the first segment demonstrate that readers initially treated the noun phrase "the doctor" as a noun phrase complement for both transitive verbs (*visited*) and intransitive verbs (*sneezed*). This misanalysis was then revised by subcategorization information for the intransitive verbs, resulting in longer reading times to the first half of 3b. For transitive verbs, reanalysis did not begin until the second segment.

While these results are consistent with delayed use of lexical information, they are far from decisive (Gorrell, 1991). Subordinate clauses such as "after the patient sneezed . . ." are typically followed by commas. The absence of a comma after the verb may have indicated to subjects that the clause was continuing (e.g., "after the child sneezed several times . . . "). This would have been reinforced by the segmentation that was used. The absence of the comma and the presentation segmentation, therefore, would have conflicted with the subcategory information of *sneezed* and the content of the noun phrase "the doctor," which, taken together, provide evidence for a clause boundary after the verb. This conflict could have resulted in elevated reading times. Indeed, in a subsequent study, Mitchell (1987) reported that these effects are eliminated when a comma is inserted after the verb. One could, of course, argue that commas are needed precisely because subcategory information is not sufficient to prevent misanalysis. However, it is unclear how one can resolve the question of whether it is the absence of the comma that causes the difficulty or the absence of verb information that makes the comma important. It seems unlikely, then, that experiments with sentences that violate standard punctuation practice will provide definitive evidence regarding when subcategorization information is accessed and used.

Ferreira and Henderson (1990) reached the same conclusions as Mitchell, using the noun phrase/sentence complement ambiguity, which does not hinge on punctuation. (See Rayner & Frazier, 1987, and Kennedy, Murray, Jennings, & Reid, 1989, for other relevant work examining this ambiguity.) They used materials like those in Example 4. Each sentence contained a verb that prefers to be used with a noun phrase complement (e.g., *suspect*) or a verb that prefers to be used with a sentence complement (e.g., *pretend*). The verb was followed by a sentence complement that did or did not contain the complementizer *that* (e.g., "[that] Jack owns credit cards").

a. She suspected Jack owns credit cards. (Example 4)
b. She suspected that Jack owns credit cards.
c. She pretended Jack owns credit cards.
d. She pretended that Jack owns credit cards.

Ferreira and Henderson used these materials in an eye-tracking study and two self-paced reading studies. The question that they addressed was whether readers would initially treat "Jack" as a noun phrase (NP) complement, regardless of verb type. If so, reading times at the disambiguating verb "owns" should be longer in the sentences without complements. This was, in fact, the result that Ferreira and Henderson observed in the eye-tracking study and in a self-paced reading study with a one-word moving window. A second self-paced reading study with an accumulating display did not produce reliable results.

Ferreira and Henderson (1990) concluded that readers initially attached the subject of the sentence complement ("Jack") as the object of the preceding verb, regardless of verb bias. This attachment would be predicted by minimal attachment because establishing an NP complement requires postulating fewer nodes than a sentence (S) complement. When the reader encountered the verb of the complement (e.g., "owns"), reanalysis was required because tensed verbs in English require a subject.

Ferreira and Henderson's (1990) results differed, however, from results obtained by Holmes, Stowe, and Cupples (1989) with similar materials. Holmes et al. conducted three experiments using several different self-paced reading methods. They found increased reading times for sentences without complementizers for noun phrase complement biased verbs, but not for sentence complement biased verbs. The results were clearest when subjects made a grammatical judgment or when an accumulating display was used. The results were less clear-cut with moving window presentation. These results were interpreted as evidence for the early use of verb subcategorization information.

Ferreira and Henderson (1991) attributed the differences between their results and those of Holmes et al. (1989) to procedural differences among the studies. In particular, they criticized the self-paced reading methods used by Holmes et al. However, there are several aspects of the Ferreira and Henderson (1990) materials that might have biased their experiment against finding immediate verb effects. First, it turns out that the verb-bias manipulation used by Ferreira and Henderson was relatively weak. Second, many of the noun phrases were implausible objects for the noun phrase complement biased verbs. Third, about half of the sentences in the experiments contained sentence complement constructions, which could have introduced a set effect in favor of this structure. We will return to these issues in more detail later. We focus here on whether the effects reported in Ferreira and Henderson (1990) actually constitute evidence for a garden-path.

The main result reported by Ferreira and Henderson (1990) was that reading times were longer for sentences without complementizers, even with sentence complement biased verbs. However, the source of the complementizer effect for these verbs might not be a local garden-path. There are at least two plausible explanations for why such an effect might have occurred even if the sentence complement was correctly parsed.

The first concerns local syntactic complexity. The structure associated with parsing a noun phrase as the subject of a sentence complement is more complex, that is, requires postulating more nodes, than the structure associated with parsing it as a noun phrase complement (object). Indeed, this complexity difference is the reason why minimal attachment predicts a noun phrase complement preference. Assume that local processing load is partially determined by local node density, as Frazier (1985) has suggested. When a complementizer is present, the sentence complement structure can be built when the complementizer *that* is encountered. However, in the absence of a complementizer, the sentence complement structure would not be built until the parser encountered the noun phrase, resulting in greater processing load than with the complementizer-present condition.[1] One might wonder why a parser that has immediate access to subcategory information would not posit a sentence complement as soon as it encountered an appropriate verb. In fact, verbs that have a preference for a sentence complement over a noun phrase complement often have a stronger preference to be used intransitively or with another complement. Thus, it is

[1] Note that the node density hypothesis does not predict that processing load will be greater for a complementizer than for a determiner of comparable length and frequency (e.g., "the man insisted that" compared with "the man visited some") because the same number of nodes would be added in either case. A complementizer would fill the comp node for an embedded (S)entence, whereas a determiner would be the (Spec)ifier of a noun phrase. Thus, two nonterminal nodes would be added to a parse tree in each case. In contrast, at least three nonterminal nodes would be required when a determiner that follows a verb is part of a noun phrase that is the subject of a sentence complement (Spec, NP, and S).

the noun phrase that provides the first reliable evidence for a sentence complement. Ferreira and Henderson (1990) typically used short one-word noun phrases (e.g., "Jack"), and complexity effects in both self-paced reading and in eye-tracking often spill over onto the next word. Therefore, one would expect a complexity difference between the complementizer-present and -absent conditions to have affected processing at both the noun and the next word, which was typically the disambiguating verb. Ferreira and Henderson actually found a suggestion of a complementizer effect at the noun, although it did not reach significance until the verb.

The second explanation hinges on the fact that many verbs, especially in written English, are typically followed by the complementizer *that* when they are used with a sentence complement. Constraint-based systems would predict that lexically specific co-occurrence information is coded by the language-processing system (Hindle & Rooth, 1990), perhaps in terms of activation levels for expected words or structures (Elman, 1991; MacDonald, 1992; Trueswell et al., 1992). If this is the case, the processing system would often not expect a sentence complement unless it encountered a *that*. If unexpected words or structures take longer to process than more expected structures, an overall complementizer effect would emerge. Of course, the complexity and *that*-expectation explanations are not incompatible with one another.

These alternative explanations for the complementizer effect present a methodological challenge, which extends beyond the noun phrase/sentence complement ambiguity. Greater processing complexity for ambiguous as compared with unambiguous structures is standardly taken as evidence for syntactic misanalysis. However, this effect might arise for other reasons, an idea that was initially explored in the early sentence-processing literature (e.g., Hakes, 1972). Thus, it becomes crucial to separate processing load effects that are due to syntactic misanalysis from those that are not.

The research reported here addressed three questions: First, how rapidly does subcategorization information become available to the processing system? Second, is there a complementizer effect for sentence complement biased verbs that is independent of syntactic misanalysis, and if so, can it be separated from syntactic misanalysis effects? Third, when is subcategorization information used in resolving the attachment of a noun phrase that would otherwise be ambiguous?

To answer these questions, we made use of three different methodologies: cross-modal naming, self-paced reading, and monitoring eye movements during reading. In Experiment 1, we used a cross-modal naming task to investigate if, with unambiguous sentences, we could find both evidence for immediate effects of verb subcategorization information and evidence for a complementizer effect. The results demonstrated a complementizer effect that was correlated with how strongly individual verbs prefer to be used with a *that* when they are followed by a sentence complement. In Experiment 2, we used self-paced reading to investigate whether subcategorization information can be used to correctly parse an otherwise ambiguous noun phrase and to investigate whether a complementizer effect would also be found in reading. The results produced both of these effects and again indicated that the complementizer effect was due to expectations for a *that*. In Experiment 3, the same materials were used in an eye-movement study in order to replicate the self-paced reading results under more natural reading conditions. Monitoring eye movements also allowed us to use measures that are arguably more sensitive to initial parsing.

Experiment 1

This experiment had two goals. The first was to determine whether subcategorization information is accessed rapidly enough to affect the processing of the word that immediately follows a verb. The second goal was to determine whether deleting the complementizer *that* makes processing a sentence complement more difficult, even when no potential ambiguity is involved.

We took advantage of the fact that pronouns in English have different morphological forms depending on their case. For example, the form for the singular masculine pronoun is *him* when it is used as an object pronoun (accusative case) and *he* when it is used as a subject pronoun (nominative case). Thus, *him* is an NP complement when it follows a verb, whereas *he* is the subject of a sentence complement. *He* and *him* were used as targets in a cross-modal integration study in which subjects heard an auditory fragment and then named a visually presented target word. The auditory fragments ended with either an NP-bias verb or an S-bias verb (e.g., "the old man accepted/insisted . . .") or with a complementizer (e.g., "the old man accepted/insisted that . . ."). Prior research using this paradigm has demonstrated that naming latencies to target words that are ungrammatical continuations of the context are longer than naming latencies to grammatical continuations (Cowart, 1987; Tyler & Marslen-Wilson, 1977; West & Stanovich, 1986).

For fragments that end with *that*, latencies to name *him* should be longer than latencies to name *he*, regardless of verb type. This is because the nominative pronoun (*he*) is grammatical in this environment, whereas the accusative pronoun (*him*) is not. This data pattern would demonstrate the sensitivity of the task and also show that subjects are able to make rapid use of case information.

Naming latencies to *he* and *him* following fragments without a complementizer (e.g., "the old man accepted/insisted . . .") can be used to diagnose whether subcategorization information is used. If this information is used, subjects should be sensitive to whether the case of the pronoun is congruous with the subcategorization properties of the verb. Naming times to *him* provide the clearest evidence. If subcategorization information is available, naming latencies should be longer for S-bias verbs than for NP-bias verbs (e.g., "the old man insisted" . . . *him* > "the old man accepted" . . . *him*). Moreover, for S-bias verbs, naming latencies to *him* should be similar regardless of whether the fragment ends with a complementizer (e.g., "the old man insisted" . . . *him* = "the old man insisted that" . . . *him*). However, if subcategorization information is not available, naming latencies to *him* should be similar for S-bias and NP-bias verbs.

Naming latencies to *he* can be used to diagnose whether or not there is a complementizer effect. If there is a complementizer effect, naming times to *he* should be longer when the fragment ends with a verb than when it ends with a complementizer. Crucially, this effect should be seen for the S-bias verbs as well as for the NP-bias verbs (e.g., "the old man insisted" . . . *he* > "the old man insisted that" . . . *he*).

In sum, this experiment should reveal whether there is a complementizer effect even under conditions where there is not a potential attachment ambiguity. Evidence for a complementizer effect would come from a main effect of complementizer presence on naming times to the subject pronoun *he*, including an effect of complementizer presence for S-bias verbs. In addition, use of subcategorization information would be reflected in an interaction between verb type and case for fragments without complementizers.

Method

Subjects

Thirty-six undergraduates from the University of Rochester participated in the experiment for course credit. All subjects were native English speakers.

Preliminary Normative Study

A sentence completion study was conducted on a separate group of 14 University of Rochester undergraduates. Target items consisted of 50 sentence fragments of the type shown in Example 5.

John insisted
[subject completion was written here]. (Example 5)

Each target item began with a person's name and ended with a verb. Fifty verbs were tested. The 50 experimental items were intermixed with a set of 30 fillers that were composed of a variety of grammatical constructions. Subjects were asked to write down, as quickly as possible, the first completion that came to mind. Each survey was later scored by hand. Completions were grouped into one of three categories: (a) sentence complement completions, (b) noun phrase complement completions, and (c) completions using some other construction (typically a prepositional phrase or infinitival complement).

Appendix A presents the results. None of the verbs we tested were always completed with sentence complements. Typically, the verbs had some completions that were neither a sentence complement nor a noun phrase complement (e.g., *about* phrases, infinitive complements, etc.). We used verbs that preferred sentence complements (S bias) and verbs that preferred noun phrase complements (NP bias). Appendix 1 indicates which verbs were used in each study.[2]

Materials

Of 16 verbs that were selected, 8 were NP-bias verbs and 8 were S-bias verbs. An additional constraint was placed on the selection of S-bias verbs. If the verb could ever be used with a noun phrase complement, the complement could not be animate. Three of the S-bias verbs had a few NP complement completions: *realize* (e.g., "Bill realized his goal"), *decided* (e.g., "Bill decided the dispute between . . . "), and *implied* (e.g., "Bill implied the answer when . . . "). The other 5 S-bias verbs were never completed with an NP complement. Each of the 16 verbs was incorporated into a sentence fragment that began with a noun phrase consisting of a determiner, an adjective, and a common noun (e.g., "the old man") and ended with either a verb ("the old man insisted") or the complementizer *that* ("the old man insisted that . . . "). Each fragment was then paired with two targets: the nominative pronoun *he* and the accusative pronoun *him*. Table 1 presents an example stimulus set. Altogether then, there were two within-item factors, complementizer and case, and one between-item factor, verb type. The four fragment–target combinations for each item were rotated through four presentation lists. The 16 experimental trials on each list were constructed so that no subject would encounter the same sentence fragment twice. The 16 experimental materials in each list were combined with 42 distractor trials of the same construction for a total of 58 trials. Each target trial was followed by at least 1 distractor trial. The distractors consisted of 30 sentence fragments of a variety of syntactic types and 12 other fragments, 6 of which had an accusative pronoun target and 6 of which had a nominative pronoun target. Distractor trials and experimental trials appeared in pseudorandom order in each list.

Table 1
Example of Target Stimuli for Experiment 1

Auditory sentence fragment	Visually presented pronoun: Accusative case	Nominative case
Sentence-bias verb		
Complementizer absent:		
"The old man insisted"	Him	He
Complementizer present:		
"The old man insisted that"	Him	He
Noun-phrase-bias verb		
Complementizer absent:		
"The young boy observed"	Him	He
Complementizer present:		
"The young boy observed that"	Him	He

The sentences were produced by a rehearsed male native English speaker and digitally recorded onto a Macintosh II computer equipped with a Farallon MacRecorder digitizer. The speech was sampled at 22 kHz and edited using Farallon SoundEdit software. Digital stereo channels were used. One channel contained the sentence fragment, and the other channel contained a brief 1-kHz tone that coincided with the offset of the final syllable of the sentence

[2] Readers may be concerned that the materials (and the correlational analyses we present later) are based on results from a sample of only 14 subjects. Susan Garnsey at the University of Illinois has recently conducted an extensive completion study using 107 subjects. All of the verbs that we used were included in her study. Garnsey's results for these verbs were strikingly similar to ours. For the verbs used in our experiments, the percentage of NP complement completions and the percentage of S complement completions were highly correlated between the two norming studies; for percentage of NP completions, Pearson $R = 0.935$, $p < .01$; for percentage of S completions, Pearson $R = 0.916$, $p < .01$. In addition, the percentage of sentence complement completions that contained a *that* was also highly correlated, Pearson $R = 0.767$, $p < .01$. When we removed the one verb that had discrepant results (*decided*), the Pearson R was 0.971.

Table 2
Naming Latencies (in ms) and Percentages of Trials Judged Not to Be Good Continuations for Experiment 1

	Complementizer present						Complementizer absent					
	He		Him		*M*		He		Him		*M*	
Verb type	Latency	% not good	Latency	% not good	Latency	% not good	Latency	% not good	Latency	% not good	Latency	% not good
Noun phrase bias	499	1	533	97	516	49	532	60	492	7	512	34
Sentence bias	486	3	539	99	513	51	519	18	532	94	526	56
M	493	2	536	98			526	39	512	51		

fragment. Both channels were recorded onto a stereo cassette tape using a cassette tape recorder.

Procedure

Subjects were tested individually. Each subject was seated in front of an IBM PC or PC compatible computer equipped with a Digitry CTS timing system. The subject wore headphones connected to the cassette tape recorder. On each trial, the auditory sentence fragment was presented binaurally. The inaudible tone at the end of the sentence fragment triggered presentation of the target word, which appeared in the center of screen. The subject then named the word aloud as fast as possible into a microphone, and naming latency was recorded using a voice key connected to the Digitry response box.

After naming the word aloud, the visual target was replaced with the words "Good Continuation?" The subject responded by pressing either a YES button or a NO button on the Digitry response box. The experimenter was present in the room and recorded any trials on which (a) the subject named the word incorrectly, (b) an extraneous noise such as a cough caused the voice key to trigger too soon, and (c) the voice key failed to respond when the word was named.

Results

As mentioned earlier, we were able to identify only eight S-bias verbs that met our criteria. With the design we used, there was a maximum of only two data points per condition per subject. In order to reduce the variability in the data, we did not analyze data from any subject who had missing data on any of the experimental trials. The experiment was run until 36 subjects met this criterion.[3] Missing data occurred on about 5% of the trials and was nearly always due to trials in which the subject did not speak loudly enough to trigger the voice relay.

Naming Latencies

The naming latency data were analyzed in analyses of variance (ANOVAs) using subjects and items as random factors. Each ANOVA contained four factors: verb type, complementizer (present or absent), case, and a grouping factor (list in the subject analysis and item group in the item analysis). Table 2 contains the mean naming latencies for each condition.

An omnibus ANOVA revealed that case of pronoun was the only main effect that approached significance, $F_1(1, 32) = 3.18, p < .1, MS_e = 5{,}104$; $F_2(1, 8) = 4.60, p < .1, MS_e = 873$. There were significant interactions between verb type and case of pronoun, $F_1(1, 32) = 7.03, p < .05, MS_e = 3{,}473$; $F_2(1, 8) = 5.67, p < .05, MS_e = 4{,}953$, and between complementizer presence and case of pronoun, $F_1(1, 32) = 20.20, p < .01, MS_e = 2{,}889$; $F_2(1, 8) = 22.49, p < .01, MS_e = 5{,}270$. The interaction between complementizer presence and verb type was marginal in the subject analysis but not significant in the item analysis, $F_1(1, 32) = 2.75, p = .1, MS_e = 1{,}991$; $F_2(1, 8) = 2.75, p > .1, MS_e = 608$. The triple interaction among case of pronoun, complementizer presence, and verb type was marginal in the subject analysis but not significant in the item analysis, $F_1(1, 32) = 3.34, p < .1, MS_e = 1{,}677$; $F_2(1, 8) = 1.67, p > .1, MS_e = 878$.

We will first consider separately the results from fragments with and without the complementizer. When the fragment ended with a complementizer (left half of Table 2), *him* took longer to name than *he* for both verb types. This was reflected in a significant effect of case, $F_1(1, 32) = 13.02, p < .01, MS_e = 5{,}229$; $F_2(1, 8) = 21.38, p < .01$; $MS_e = 694$; no effect of verb type (Fs < 1); and no interaction with verb type, $F_1(1, 32) = 2.26$, $F_2(1, 12) = 1.20$. This pattern was expected because accusative marked pronouns cannot be in the subject position of a sentence complement. Thus, this result demonstrates the sensitivity of the experiment and also demonstrates that subjects make immediate use of case information.

The pattern for the fragments without the complementizer was clearly different (right half of Table 2). The fastest naming times were to *him* following the NP-bias verbs. The slowest naming times were to *him* following an S-bias verb and to *he* following an NP-bias verb. Naming times to *he* following an S-bias verb were intermediate. This resulted in a reliable interaction between case and verb type, $F_1(1, 32) = 7.25, p < .05, MS_e = 3{,}684$; $F_2(1, 8) = 7.08, p < .05, MS_e = 706$. Simple effects tests revealed that the effect of verb type for the naming of *him* was reliable in the subject analysis and marginally significant in the item analysis, $F_1(1, 32) = 9.89, p < .01, MS_e = 3{,}013$; $F_2(1, 8) = 4.12, p < .1, MS_e = 1{,}038$. There were no reliable effects for the naming of *he* (Fs < 1). The effects for *him* demonstrate that verb subcategorization information is available when the pronoun is being processed. The results for *he* suggest that there is also

[3] Sixty subjects were run to meet this criterion. An analysis that included subjects with missing data revealed the same pattern as reported here, although it was somewhat noisier.

a complementizer effect associated with establishing a sentence complement. In order to explore this in more detail, it will be useful to consider first the judgment results and then the combined results of judgments and latencies for the pronoun *he*.

"Good Continuation" Judgments

Table 2 also presents the mean percent *no* responses to the "Good Continuation?" prompt in the eight conditions of the experiment. As shown in the table, the type of pronoun had a large effect on judgments when the complementizer *that* was present: When the target was the nominative pronoun *he*, almost all of the trials were judged as good continuations of the sentence; conversely, when the target was *him*, almost none of the trials were judged as good continuations of the sentence. When the complementizer was absent, verb type had a large effect on the judgments to the pronoun *him*: When the sentence fragment contained an NP-bias verb, almost all of the *him*s were judged as good continuations, whereas almost none of the *him*s were judged as good continuations when the fragment had an S-bias verb. The judgments to the pronoun *he* showed the opposite effect. Only 18% of the *he*s were judged as not being good continuations when the fragment contained an S-bias verb, whereas 60% of the *he*s were judged as not being good continuations when the fragment contained an NP-bias verb. The average percent *no* responses for each subject and each item were analyzed in separate ANOVAs with four factors: list (four lists) or item group (four groups), verb type (NP bias or S bias), complementizer presence (*that* or no *that*), and target pronoun type (accusative [*him*] or nominative [*he*]).

All of the main effects and interactions were significant or approached significance, including the effect of verb type, $F_1(1, 32) = 40.50, p < .01, MS_e = 263$; $F_2(1, 8) = 77.72, p < .01, MS_e = 30$; the effect of complementizer presence, $F_1(1, 32) = 6.47, p < .05, MS_e = 302$; $F_2(1, 8) = 4.24, p < .1, MS_e = 99$; the effect of case of pronoun, $F_1(1, 32) = 612.10, p < .01, MS_e = 341$; $F_2(1, 8) = 1{,}581.84, p < .01, MS_e = 30$; the interaction between verb type and case of pronoun, $F_1(1, 32) = 223.20, p < .01, MS_e = 336$; $F_2(1, 8) = 512.92, p < .01, MS_e = 30$; the interaction between verb type and complementizer presence, $F_1(1, 32) = 35.27, p < .01, MS_e = 237$; $F_2(1, 8) = 20.84, p < .01$; $MS_e = 99$; the interaction between case of pronoun and complementizer presence, $F_1(1, 32) = 297.28, p < .01, MS_e = 293$; $F_2(1, 8) = 338.05, p < .01, MS_e = 84$; and the triple interaction between verb type, complementizer presence, and case of pronoun, $F_1(1, 32) = 256.27, p < .01, MS_e = 293$; $F_2(1, 8) = 191.58, p < .01, MS_e = 84$.

The Pronoun He

As can be seen in Table 2, naming latencies to the pronoun *he* showed no hint of an interaction between verb type and complementizer presence: *He* was easier to name when a complementizer was present. An analysis using the naming times to *he* revealed an effect of complementizer presence, $F_1(1, 32) = 18.93, p < .01, MS_e = 1{,}998$; $F_2(1, 8) = 18.72, p < .01, MS_e = 389$; but no effect of verb type, $F_1(1, 32) = 1.53, MS_e = 3{,}283$; $F_2(1, 8) = 0.23, MS_e = 608$. The factors did not interact ($Fs < 1$).

Although the percentage of *no* responses to *he* increases for both verb types when the complementizer is absent, the NP bias show a much larger increase. An analysis on these responses revealed a significant interaction between complementizer presence and verb type, $F_1(1, 32) = 45.22, p < .01, MS_e = 369$; $F_2(1, 8) = 21.68, p < .01, MS_e = 152$. The small effect of complementizer presence for the S-bias verbs was significant in the subject and marginal in the item analyses, $F_1(1, 32) = 9.68, p < .01, MS_e = 434$; $F_2(1, 4) = 7.20, p < .1, MS_e = 154$, and the effect of complementizer presence for the NP-bias verbs was significant in both analyses, $F_1(1, 32) = 123.79, p < .01, MS_e = 495$; $F_2(1, 4) = 87.12, p < .01, MS_e = 151$.

The combined results for *he* were quite revealing. For the S-bias verbs, subjects clearly had more difficulty naming the pronoun when it was not preceded by a complementizer, despite the fact that the case information was unambiguous and despite the fact that verb subcategory information was available, as revealed by the results with *him*. Therefore, the longer naming times to *he* in the complementizer-absent condition in S-bias sentences are not likely to be due to a misanalysis effect. This is supported by the fact that subjects usually judged *he* to be a good continuation after the S-bias verbs. While similar latency effects obtained for the stimuli with NP-bias verbs, these elevated naming times to *he* in the absence of a complementizer may be due to a mixture of a complementizer effect and a grammaticality effect. Support for this comes from the fact that 60% of the *he* trials were judged to be bad continuations in the complementizer-absent condition. However, the grammaticality effect and the complementizer effect were clearly not additive.

Discussion

The results indicate that verb subcategorization information was accessed rapidly. In addition, there was a complementizer effect that was unrelated to syntactic misanalysis. For the fragments without a complementizer, there was a clear interaction between verb type and case of the target pronoun, indicating that subcategorization information was used. Moreover, naming times to object pronouns (*him*) were equally slow following S-bias verbs with and without complementizers. Evidence for an increase in processing difficulty in the absence of a complementizer came from a main effect of complementizer on naming times to *he*. Crucially, naming times to *he* were longer following an S-bias verb without a complementizer than an S-bias verb with a complementizer. This effect cannot be attributed to a temporary syntactic misanalysis for three reasons: (a) subcategorization was clearly available, (b) subjects made immediate use of case information, and (c) the pronoun *he* is unambiguously case-marked as a subject pronoun.

The conclusion that subcategorization information becomes available shortly after a verb is recognized is supported by several recent studies. Shapiro and colleagues have found that lexical decision times to a visually presented target are affected by the argument structure of the preceding verb in an auditory fragment (Shapiro, Nagel, & Levin, in press; Shapiro, Zurif, & Grimshaw, 1987, 1989; but cf. Schmauder, Kennison, & Clifton, 1991). Gorrell (1991) reported faster lexical decision times to noun targets that followed visually presented sentence fragments when the fragment ended in an obligatorily transitive verb (e.g., *permit*) as compared with an obligatorily intransitive verb (e.g., *remain*). Trueswell (1993) used the verbs from the present experiment as targets in a cross-modal naming study in which the congruence of the verb as a continuation of an auditory fragment depended on the verb's subcategorization properties. Naming latencies to NP-bias and S-bias verbs did not differ in contexts in which they were both syntactically permissible (e.g., "the old man . . . accepted/insisted"). However, latencies to S-bias verbs were longer than NP-bias verbs in contexts in which only a transitive verb was grammatical (e.g., "the old man was . . . accepted/*insisted").

The locus of the effects obtained in the present study merits comment. It seems likely that some of the effects are postlexical and that they are due in part to the language production system (Tanenhaus & Lucas, 1987; West & Stanovich, 1986). In addition, the "Good Continuation?" judgment may have contributed to the effects, perhaps by making subjects more sensitive to subcategorization information than they might have otherwise been. However, Boland (1991, in press) also found that subcategorization affected cross-modal naming in a task that did not include a continuation judgment. In Boland's study, nominative and accusative plural pronouns (e.g., *they* and *them*) were presented as targets following auditory fragments that ended in either an S-bias verb or an NP-bias verb that did not permit a sentence complement (e.g., *visited*). Verb type affected naming times to accusative but not nominative pronouns, the same pattern reported here. Boland also showed that cross-modal naming was not affected by either thematic congruity or plausibility, in contrast to lexical decision, which showed effects of both of these variables. This suggests that the cross-modal task is primarily sensitive to syntactic processes. Boland did not, however, include a complementizer condition. It also remains to be seen whether cross-modal naming would be selectively sensitive to syntactic congruity when continuation judgments are used.

While these are interesting issues, what is crucial for the present investigation is that a complementizer effect occurred even when subcategorization information was being used. Thus, a complementizer effect could easily be mistaken for a garden-path under conditions where the resolution of a potential attachment ambiguity depends on subcategorization constraints.

Earlier, we hypothesized two different types of explanations for why a complementizer effect could occur for S-bias verbs in the absence of any syntactic misanalysis. One explanation was that building the structure for a noun phrase that is the subject of a sentence complement requires more local structure building at the noun phrase when there is not a complementizer. The second explanation was that there is

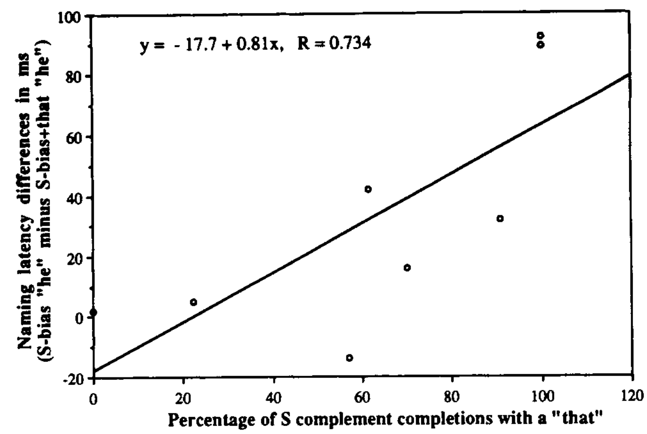

Figure 1. Scattergram plotting the *he* complementizer effect (in ms) against the percentage of sentence complement completions that began with a *that* for each sentence (S) bias verb.

a general preference for a sentence complement to be introduced by a *that*, although the preference varies across verbs. If this information is coded by the processing system in terms of activation levels for potential structures associated with the verb, then, after some verbs, the parser would not be expecting a sentence complement unless it encountered a *that*, whereas for other verbs a *that*-less sentence complement would be a likely structure.

For the S-bias verbs used in this experiment, 58% of the sentence complement completions contained a *that*. However, the preference for a *that* varied across verbs and it was unrelated to the strength of the verb bias; that is, it was unrelated to either the percentage of sentence complement completions or noun phrase complement completions. As a result, it is possible to perform post hoc correlations to test between a local complexity and a *that*-preference explanation for the complementizer effect for S-bias verbs.[4] If the complementizer effect for naming *he* with S-bias verbs is actually due to a lexical preference for a *that*, the size of the effect for individual verbs should vary with the strength of their *that* preference. S-bias verbs that tend not to be used with a *that* in a sentence complement should show little or no complementizer effect, whereas S-bias verbs that tend to be used with a *that* should show a large complementizer effect. Figure 1 presents a scattergram in which the complementizer effect is plotted against the percentage of sentence complement completions that contained a *that*. A regression analysis between these two measures revealed a significant positive correlation, Pearson $r = 0.734$, $F(1, 6) = 7.38$, $p < .05$, $MS_e = 6{,}035$, with a slope of 0.81 and an intercept of -17.7 ms. An additional regression analysis was conducted on a transformation of the percentages ($\log(p/1-p)$) because the per-

[4] The same correlation with *that* preference cannot be performed on NP-bias verbs because almost all sentence complement completions with these verbs contained a *that*, resulting in primarily 100% *that* preferences (see Appendix A). Moreover, the data in this group are too sparse, because, by definition, an NP-bias verb was hardly ever completed with a sentence complement.

centage range is bounded. The correlation was also significant, Pearson $r = 0.829$, $F(1, 6) = 13.13$, $p < .05$, $MS_e = 7{,}511$. The *that* preference for S-bias verbs did not correlate with differences in verb bias within the S-bias group (i.e., the percentage of sentence complement completions, noun phrase complement completions, or their differences), $Fs < 1$ for transformed and untransformed percentages.

The results of these correlations strongly support the *that*-preference explanation. The size of the complementizer effect for individual S-bias verbs was strongly correlated with the degree of *that* preference, and there was no suggestion of a residual complementizer effect. These correlations, in conjunction with the latency results, demonstrate that the processing system is sensitive to both subcategory information and subtle patterns of lexical co-occurrence.

Experiment 2

This experiment used self-paced reading times to investigate when subcategorization information is used in resolving the attachment of a noun phrase that would otherwise be ambiguous. It was important to determine whether *that*-preference effects also occur in reading and, if so, are responsible for effects that have been previously interpreted as misanalysis effects due to delayed use of verb information.

This study was similar in design to the reading studies conducted by Holmes et al. (1989) and Ferreira and Henderson (1991). We compared reading times to sentential complements following verbs that prefer NP complements and verbs that prefer S complements. The sentence complement was preceded by the complementizer *that* or directly followed the matrix verb. All of the sentence complements began with a two-word noun phrase that was a plausible object for the sentences with NP-bias verbs. Sample sentences are presented in Example 6:

a. The student forgot (that) the solution was in the back of the book. (NP-bias) (Example 6)
b. The student hoped (that) the solution was in the back of the book. (S-bias)

For the NP-bias verbs without a complementizer, readers should initially interpret the noun phrase after the verb as an NP complement. Consequently, reanalysis would be required when the following verb provides unambiguous syntactic evidence that the noun phrase was actually the subject of a sentence complement. The results for the S-bias verbs depend on when subcategorization information is used. If use of subcategorization information is delayed, the results for the S-bias verbs should be similar to those for the NP-bias verbs. If subcategorization information is used quickly, as the previous experiment suggests, the noun phrase will be correctly analyzed as the subject of a sentence complement. Thus, reanalysis would not be required at the verb. In addition, given the results of Experiment 1, there should be a *that*-preference effect at the noun phrase for sentences with S-bias verbs without a complementizer.

Ferreira and Henderson (1990) used self-paced reading with similar sentences but found only delayed effects of verb bias. However, there are a number of problems with the Ferreira and Henderson materials that could have contributed to this result. First, their verb bias manipulation was relatively weak. Our sentence completion norms revealed that of the 20 S-bias verbs used by Ferreira and Henderson, 2 verbs actually had a strong noun phrase bias (NP bias), and 5 verbs showed little or no preference toward either complementizer type. Overall, Ferreira and Henderson's S-bias verbs had 15% noun phrase complement completions and 43% sentential complement completions. Of the 20 NP-bias verbs used by Ferreira and Henderson, 4 verbs showed a strong sentential complement bias (S-bias), and 3 verbs showed little or no preference. Overall, Ferreira and Henderson's NP-bias verbs had 58% NP completions and 23% S completions.

The importance of using strongly biased verbs is highlighted by a recent study by Shapiro et al. (in press). Shapiro et al. showed that there are clear individual differences in preferred completions for verbs with different argument structures. In their experiments, which used a cross-modal lexical decision paradigm, no verb effects emerged when verbs were divided according to group preferences. However, clear effects emerged when verb preferences were determined individually for each subject. The likelihood of verb effects being masked by individual differences is greatest when verb bias is relatively weak.

Second, inspection of the materials published in Ferreira and Henderson (1990) revealed that about half of the noun phrases in the NP-bias sentences were implausible direct objects of the verb (e.g., "Sue wrote Iowa elected better people," "She admitted fish like the water too"). Because plausibility can have immediate effects on ambiguity resolution (Trueswell et al., 1992), this could have reduced the size of the misanalysis effect for NP-bias verbs.

Finally, of the 152 sentences used in the Ferreira and Henderson experiment, 80 were target sentences with sentence complements. Repeated use of sentence complements could have introduced set effects in favor of this construction (Mehler & Carey, 1967).

The cumulative effect of weakly biased verbs, noun phrases that were implausible objects, and the repeated use of sentence complements could have been to reduce the garden-path for Ferreira and Henderson's NP-bias sentences, while leaving intact a *that* preference effect for S-bias sentences. Because Ferreira and Henderson (1990) typically used only a single word noun phrase, a *that* preference for S-bias verbs is likely to appear on the disambiguating verb rather than immediately on the noun. These factors taken together could have resulted in longer reading times at the disambiguating region for both S-bias and NP-bias verbs in the complementizer-absent conditions, with little evidence of strong reanalysis effects for either verb type.

In contrast, the present study used strongly biased verbs, noun phrases that were plausible objects for NP-bias verbs, and a relatively small proportion of sentences with sentence complements. We also used two-word noun phrases to increase the likelihood that a *that*-preference effect would be resolved prior to the disambiguating region (i.e., the verb phrase in the sentence complement).

Method

Subjects

Forty subjects from the University of Rochester participated in the experiment for course credit. All subjects were native English speakers.

Materials

The experimental materials were generated from 20 verbs used in the sentence completion norms (see Appendix B). An example set appears in Example 6, given earlier. Each sentence began with a simple noun phrase, containing a determiner and a noun. The first factor in the experiment was whether the matrix verb in the sentence had bias toward taking a noun phrase object (NP bias) or a sentence complement (S bias). Two additional verbs that also showed no completions using a noun phrase object were added to the S-bias group. Also, 2 additional verbs that tend to be completed with direct objects were added to the NP-bias verb group. On the basis of the earlier sentence completion study, the S-bias verbs had 4% noun phrase completions and 64% sentence complement completions, whereas the NP-bias verbs had 78% noun phrase completions and 9% sentence complement completions. Following the verb was a sentence complement that began with a definite NP. The second factor in the experiment was whether this sentence complement was preceded with the complementizer *that* or not. The noun phrases that began the sentence complements were chosen to be highly plausible (potential) objects for the sentences with NP-bias verbs. In a separate norming study, sentence completions for fragments ending with the noun phrase (e.g., "The student hoped/forgot the solution . . .") resulted in 99% noun phrase complement completions for the fragments with NP-bias verbs and 88% sentence complement completions for the S-bias verbs. These percentages were based on completions from 10 subjects.

Each target sentence was followed by a sentence that naturally continued the description or story begun by the first sentence. Four presentation lists were constructed by pseudorandomly combining the 20 experimental materials with 40 distractor texts for a total of 60 trials. Each target text was followed by at least 1 distractor text. Each distractor text consisted of a sentence pair that sounded natural together. Each text contained a variety of syntactic structures and verbs with various subcategorizations. Ten of the distractors had initial sentences that (a) contained a matrix verb that subcategorizes for a sentence complement (and was different from the experimental verbs) and (b) had a noun phrase complement in object position, following the verb. This was done to avoid introducing a bias toward the sentence complement construction. Thus, out of all the sentences in the study, 17% (20 of 120) had a sentence complement immediately following the main verb.

Procedure

The stimuli were presented on an IBM or IBM-compatible PC equipped with a color monitor and Digitry CTS timing system and response box. The monitor was set to a text mode of 80 characters per line. The subject was seated approximately 72 cm from the monitor (although this distance was not controlled), and the visual angle for each character was approximately 22 min arc. At the beginning of each trial, the entire text was displayed on the screen, with each character (except spaces) covered by a single dash (–). The subject would then press a button marked SCROLL to uncover and read the first word. With each press of the SCROLL button, the next word in the sentence would be uncovered and the previous word would be covered up with dashes again. This was repeated until the end of the text. Reaction times were collected for the reading of each word in each target sentence. After about a third of the texts, a yes/no comprehension question was displayed on the screen, and the subject responded by pressing YES or NO on the button box. Subjects were given feedback concerning whether their answer was correct.

Results

Figure 2 presents the self-paced reading times to the matrix verb and the first four words of the sentence complement for each of the four conditions. (Reading times to the word *that* were not collected.) The mean reading times for each subject and item were analyzed in separate ANOVAs with four factors: list (four lists) or item group (four groups); verb type (NP bias, S bias); complementizer presence (*that* or no *that*); and word position (matrix verb, *the*, noun, *be* verb, and the next word). We will first discuss overall effects and interactions and then look at separate analyses for each word position.

Overall Analysis Across Word Position

An effect of word position was significant in the subject and item analysis, $F_1(4, 33) = 4.52, p < .01, MS_e = 6{,}124$; $F_2(4, 13) = 5.73, p < .01, MS_e = 2{,}425$. We report Hyunh-Feldt adjusted probability levels for all effects involving word position, because it has more than two levels that are not independent of one another. However, we report nonadjusted degrees of freedom. There was also an overall effect of complementizer presence, $F_1(1, 36) = 13.85, p < .01, MS_e = 5{,}942$; $F_2(1, 16), = 6.34, p < .05, MS_e = 6{,}467$; no effect of verb type (Fs < 1); and no interaction between these factors (Fs < 1). However, these factors did interact with word position. There were significant interactions between verb type and word position, $F_1(4, 33) = 3.48, p < .05, MS_e = 3{,}045$; $F_2(4, 13) = 2.86, p < .05, MS_e = 1{,}860$; and complementizer presence and word position, $F_1(4, 33) = 2.91, p < .05, MS_e = 3{,}821$; $F_2(4, 13) = 3.76, p < .05, MS_e = 1{,}480$. In addition, the triple interaction between verb type,

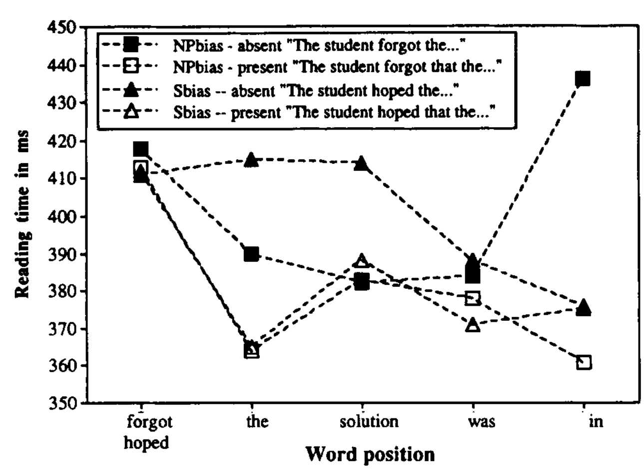

Figure 2. Word-by-word self-paced reading times (in ms). (NP = noun phrase; S = sentence.)

complementizer presence, and word position was significant, $F_1(4, 33) = 5.31, p < .01, MS_e = 3{,}241$; $F_2(4, 13) = 6.24, p < .01, MS_e = 1{,}377$.

Reading Times at the Matrix Verb

There were no effects or interactions between factors at the main verb of the sentence (Fs < 1).

Reading Times at the Determiner

At the determiner (*the*), there was an immediate increase in reading times for sentences without the complementizer *that* as compared with those sentences containing the *that*, with the largest difference occurring for the S-bias verbs. There was a main effect of complementizer presence at this position, $F_1(1, 36) = 15.12, p < .01, MS_e = 3{,}821$; $F_2(1, 16) = 10.97, p < .01, MS_e = 2{,}630$; no effect of verb type, $F_1(1, 36) = 1.51, MS_e = 4{,}102$; $F_2(1, 16) = 0.50, MS_e = 6{,}154$; and no interaction between these factors, $F_1(1, 36) = 1.36, MS_e = 4{,}110$; $F_2(1, 16) = 1.13, MS_e = 2{,}417$. An examination of the simple effects revealed no reliable difference between the verb types for the sentences without a complementizer, $F_1(1, 36) = 2.00, MS_e = 5{,}883$; $F_2(1, 16) = 1.05, MS_e = 5{,}525$.

Reading Times at the Noun

At the noun, the S-bias sentences showed a smaller difference between sentences without the complementizer *that* and sentences with the complementizer *that*, and no difference in the reading times for NP-bias sentences. There was a significant effect of verb type for the subject analysis but not for the item analysis, $F_1(1, 36) = 4.46, p < .05, MS_e = 3{,}163$; $F_2(1, 16) = 0.75, MS_e = 9{,}327$; and no effect of complementizer presence, $F_1(1, 36) = 1.31, MS_e = 4{,}666$; $F_2(1, 16) = 1.06, MS_e = 2{,}896$. The interaction between verb type and complementizer did not approach significance, $F_1(1, 36) = 1.88, MS_e = 3{,}868$; $F_2(1, 16) = 1.50, MS_e = 2{,}422$. An examination of the simple effects revealed that the difference between the verb types for the sentences without a complementizer was significant in the subject analysis, but not significant in the item analysis, $F_1(1, 36) = 5.06, p < .05, MS_e = 4{,}118$; $F_2(1, 16) = 1.67, MS_e = 6{,}216$.

Reading Times at the Complement Verb

At the complement verb, there were no effects or interactions that reached significance, all Fs < 1, except complementizer presence, $F_1(1, 36) = 2.63, MS_e = 2{,}010$; $F_2(1, 16) = 1.73, MS_e = 1{,}545$.

Reading Times at the Final Position

At the word after the *be* verb, NP-bias sentences showed a large increase in reading times for sentences that did not contain a *that* as compared with sentences that did. S-bias sentences did not show an increase. This difference was realized in the analysis as a significant interaction between verb type and complementizer presence, $F_1(1, 36) = 10.34, p < .01, MS_e = 5{,}317$; $F_2(1, 16) = 10.96, p < .01, MS_e = 2{,}518$. There was also an effect of complementizer presence, $F_1(1, 36) = 8.34, p < .01, MS_e = 6{,}900$; $F_2(1, 16) = 9.43, p < .01, MS_e = 3{,}038$, whereas the effect of verb type only approached significance in the subject analysis, $F_1(1, 36) = 3.54, p < .10, MS_e = 6{,}098$; $F+_2(1, 16) = 1.63, MS_e = 6{,}652$. Simple effects revealed that the interaction between these factors was due to a significant effect of complementizer presence in the NP-bias sentences, $F_1(1, 36) = 11.10, p < .01, MS_e = 10{,}137$; $F_2(1, 16) = 13.28, p < .01, MS_e = 4{,}236$; and no effect of complementizer presence in the S-bias sentences (Fs < 1).

Discussion

The results clearly demonstrated that subcategorization information is used to determine the correct attachment of a noun phrase that would be otherwise ambiguous between an NP complement and the subject of a sentence complement. When the preceding verb had a strong bias in favor of an NP complement, subjects experienced difficulty when the NP was disambiguated as the subject of a sentence complement: NP-bias sentences without a complementizer showed a large elevation at the word after the verb in the sentence complement, whereas no such difficulty obtained for S-bias verbs. (Moving-window reading time differences often appear one or two words downstream, especially when the reading rate is reasonably fast.) This pattern of results suggests that the noun phrase was taken to be a noun phrase complement when it followed an NP-bias verb and the subject of a sentence complement when it followed an S-bias verb.

In addition, readers had more difficulty at the determiner *the* immediately after the verb when the complementizer was absent, regardless of verb type. Although reading times to the determiner for S-bias sentences without a complementizer were numerically longer than reading times at the determiner for NP-bias sentences, the reading times were statistically indistinguishable, and both were reliably greater than the complementizer-present sentences. This effect is difficult to explain with either a lexically based parsing proposal or a lexical filtering proposal. The small effect for NP-bias sentences cannot be attributed to either a misanalysis effect or a complexity effect because the preferred NP complement construction is syntactically less complex. The elevations at the determiner, however, may be explained by the difference in lexical content in the word prior to the determiner. The longer reading times at the determiner may simply be a spillover effect from the verb. In the complementizer-absent stimuli, *the* was preceded by a complex content word, a verb, whereas in the complementizer-present stimuli, *the* was preceded by a high-frequency function word *that*. These differences in content are likely to be realized in elevations in reading times, which will spill over onto the following word.

Finally, readers had more difficulty at the head of a noun phrase following an S-bias verb when there was not a complementizer: Reading times at the noun for S-bias sentences without a complementizer were numerically and statistically different from the corresponding NP-bias sentences.

One might argue that the effect at the noun is due to rapid lexical filtering. On this account, the parser attached the noun phrase as the object of the verb and then immediately revised the analysis. Recall, however, that a similar complementizer effect was found in Experiment 1 for pronouns that are unambiguously the subject of a sentence complement. For a lexical filtering hypothesis to be compelling, then, it would first be necessary to demonstrate an effect above and beyond what would be expected for unambiguous structures.

Fortunately, it is possible to provide a more direct test of the locus of the complementizer effect by examining the correlation between the size of the effect and the strength of the *that* preference for the S-bias verbs. If the effect is a *that*-preference effect, as in Experiment 1, there should be a correlation between strength of preference and the size of the complementizer effect. Indeed, regression analyses using these factors revealed a positive correlation between the preference for a *that* and the effect size at the noun. Table 3 presents these correlations for both the complementizer effect within S-bias sentences (complementizer-absent sentences minus complementizer-present) and the verb-type effect for complementizer-absent stimuli (S bias minus NP bias for sentences without a complementizer). Neither of these effects correlated with verb biases (all $Fs < 1$). We also examined correlations at the determiner. As expected, reading times did not correlate with either verb preferences or *that* preferences (all $Fs < 1$), further suggesting that the effects at this position were independent of factors related to verb type.

The regression analyses that we conducted to examine correlations with *that* preference at the noun allowed a critical prediction made by the lexical filtering hypothesis to be tested. The lexical filtering hypothesis predicts that a noun phrase following an S-bias verb will be initially treated as an NP complement, resulting in a need for subsequent reanalysis. This reanalysis should result in greater processing difficulty for noun phrases following S-bias verbs without complementizers as compared to with complementizers. A revision effect should occur even for S-bias verbs that typically occur without a complementizer. Therefore, the zero intercept for the regression equation relating *that* preference to the difference between complementizer-present and -absent conditions should be positive for the untransformed data. In fact, there was no hint of a residual complementizer effect. The intercept was actually negative. Note that the zero intercept of transformed data does not correspond to a 0% *that* preference. In fact, this zero intercept corresponds to about a 50% *that* preference and should therefore be a positive value. The predicted value corresponding to an actual 0% *that* preference in these regressions is also slightly negative. This was also true for all other regressions with transformed percentages reported in this article.

Table 3
Correlations of Self-Paced Reading Time Differences at the Noun With That *Preference for Experiment 2*

Independent measure	Slope	Intercept	Pearson r	$F(1, 8)$	$p <$
Complementizer effect for sentence-bias sentences					
% *that*	1.29	−44.7	.597	4.44	.07
Trans(%)	10.6	+18.8	.507	2.77	
Verb-type effect for sentences without a complementizer					
% *that*	1.84	−74.0	.607	4.67	.06
Trans(%)	18.4	+20.0	.594	4.37	.07

Note. Trans(%) = transformed percentages. Intercepts for transformed data do not correspond to 0% *that* preference.

Experiment 3

This experiment used the same materials as those used in Experiment 2. Instead of collecting self-paced reading times, we monitored eye movements as subjects read each sentence. There are several reasons why it was important to replicate the self-paced reading results with eye-movement data. Self-paced reading with single-word presentation forces readers to fixate on every word and does not allow parafoveal preview of upcoming material. As Ferreira and Henderson (1990) suggested, it is possible that readers may rely on lexical information more in single-word, self-paced reading than they would with whole-sentence presentation. In general, studies that have directly compared self-paced reading with a single-word moving window and eye-tracking with whole-sentence presentation have found similar results (e.g., Britt, Perfetti, Garrod, & Rayner, 1992; Ferreira & Clifton, 1986; Ferreira & Henderson, 1990). However, there are some exceptions. For example, the effects of some thematic and discourse constraints on syntactic ambiguity resolution with relative clauses (e.g., "the student spotted by . . . ") are reduced or eliminated when single-word presentation prevents the reader from parafoveally viewing a disambiguating preposition (Burgess & Tanenhaus, 1992; Spivey-Knowlton et al., 1992; Trueswell et al., 1992).

Eye-movement data can also provide several types of measures that can be used to determine the time course with which information is used in reading (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Some of these measures might be sensitive to small effects that other tasks would be less likely to detect. Thus, it could be argued that there is a small misanalysis effect for S-bias verbs that might be detected with eye movements, but not with self-paced reading times.

Method

Subjects

Twenty-four University of Rochester students participated in the experiment. Subjects were paid $7 for each hour of their time.

Equipment

The eye movements of each subject were recorded using a Stanford Research Institute Dual Purkinje Eyetracker (Fifth Generation). The eyetracker transmitted information concerning horizontal and vertical eye position angle to a Macintosh II computer equipped with an analog to digital conversion board. Eye position was determined by sampling every millisecond both the horizontal and vertical eye angles and blink signals from the eyetracker. At the end of each trial, fixation positions and durations were computed and stored to disk. Each fixation was represented by an x and y screen coordinate, a starting time, and an ending time. Although eye movements were recorded from the right eye, viewing was binocular. Stimuli were displayed on a 13-inch AppleColor High Resolution RGB monitor.

Materials

The materials were identical to those used in the previous experiment.

Procedure

Because small head movements decrease the accuracy of the eyetracker, a bite bar was made for each subject at the beginning of the testing session. Subjects were given instructions and seated in front of the computer screen, with the subject's eyes approximately 64 cm from the screen. All sentences appeared in mixed case in Courier 14-point font. The visual angle of each character was slightly greater than 12 min arc, allowing for one character resolution from the eyetracker position signals. At the beginning of the experiment, the brightness of the monitor was adjusted to the subject's comfort. The eyetracker was aligned and the signal from the eyetracker was calibrated with the screen coordinates. During the calibration procedure, the subject fixated on a series of screen positions, with the computer sampling the eyetracker at each position. These samples were then used by the computer to derive a set of linear equations that converted the horizontal eye position signal into horizontal screen coordinates and the vertical signal into vertical screen coordinates.

Each trial consisted of the presentation of the sentence pair. Each line contained no more than 65 characters, and all the critical scoring regions appeared on the first line of text. Before the sentences were presented, a fixation cross was displayed at the starting position of the first sentence. The subject fixated on the cross and pressed the computer mouse button to display the sentences. The subject read the sentences silently and then pressed the button again to signal that he or she was finished. After each sentence pair, the calibration was checked by displaying a line trace controlled by the subject's eye movements and the fixation cross of the next trial. The line trace was a line that was continually drawn out on the screen indicating the subject's latest eye position. If the experimenter judged that the eye position did not adequately line up, the computer was recalibrated. (Recalibrations were typically not necessary.) On about a third of the trials, a yes/no question appeared on the screen prior to the line trace test. Subjects answered the question by moving the mouse into either a YES box or a NO box and clicking the mouse button. Subjects were given feedback as to whether their answer was correct. Each reading session lasted approximately 25 min. Subjects were allowed to release from the bite bar between sentences at any time during the experiment. Subjects usually took one or two breaks.

Results and Discussion

The results from this study are divided into three sections: total processing effects, initial processing effects, and reprocessing effects.

Total Processing

The test sentences were divided into four regions: (a) the subject noun phrase of the sentence, (b) the matrix verb, (c) the subject noun phrase of the sentence complement, and (d) the three words following the noun phrase. Table 4 presents mean total reading times for each region. Total reading times corresponded to the total amount of time spent within a region, including rereads of a region. As shown in the table, subcategory biases associated with the matrix verbs clearly influenced reading times. For NP-bias verbs, sentences without the complementizer took longer to read than sentences with the complementizer. For S-bias verbs, sentences without the complementizer took only slightly longer to read than sentences with the complementizer. In addition, sentences with a *that* also appear to show a small effect of verb type, with NP-bias sentences taking slightly longer to read than S-bias sentences, especially in the final region.

Subject and item means were entered into separate ANOVAs with four factors: list (four lists) or item group (four groups); region (matrix verb, sentence complement subject NP, and sentence complement verb [three words]); verb type (S bias and NP bias); and complementizer (present and absent). When collapsing across all of the scoring regions, there was a reliable interaction between verb type and complementizer presence, $F_1(1, 20) = 11.76$, $p < .01$, $MS_e = 27{,}681$; $F_2(1, 16) = 7.32$, $p < .05$, $MS_e = 43{,}429$. In addition, there were main effects of verb type, $F_1(1, 20) = 23.10$, $p < .01$, $MS_e = 40{,}706$; $F_2(1, 16) = 10.42$, $p < .01$, $MS_e = 71{,}994$; and complementizer presence, $F_1(1, 20) = 30.63$, $p < .01$, $MS_e = 25{,}422$; $F_2(1, 16) = 28.99$, $p < .01$, $MS_e = 22{,}083$. Simple effects revealed a clear effect of complementizer presence for the NP-bias sentences, $F_1(1, 20) = 25.88$, $p < .01$, $MS_e = 40{,}787$; $F_2(1, 16) = 24.09$, $p < .01$, $MS_e = 38{,}616$. The effect of complementizer presence for the S-bias sentences, however, was marginal in the subject analysis and not significant in the item analysis, $F_1(1, 20) = 3.95$,

Table 4
Mean Total Reading Times (in ms) for Each Scoring Region for Experiment 3

Scoring region	Verb type	Complementizer: Absent	Complementizer: Present	Δ	*M*
"The student"	S bias	459	446	+13	453
	NP bias	541	471	+70	506
	M	500	459	—	—
"forgot/hoped"	S bias	440	433	+7	437
	NP bias	554	433	+121	494
	M	497	433	—	—
"the solution"	S bias	557	523	+34[a]	540
	NP bias	677	555	+122	616
	M	617	539	—	—
"was in the"	S bias	761	688	+73[a]	725
	NP bias	1,073	793	+280	933
	M	917	741	—	—

Note. S = sentence; NP = noun phrase.
[a] Difference correlated with lexically specific *that* preferences.

$p < .10$, $MS_e = 12{,}315$; $F_2(1, 16) = 1.04$, $MS_e = 26{,}896$. Finally, there was an overall effect of scoring region, $F_1(1, 20) = 116.28$, $p < .01$, $MS_e = 23{,}421$; $F_2(1, 16) = 70.00$, $p < .01$, $MS_e = 32.727$.

Analysis by region. Similar ANOVAs were conducted at each scoring region. To conserve space, only the analysis of the subject NP and verb phrase regions of the sentence complement will be reported. At the noun phrase region, there was a main effect of verb type, $F_1(1, 20) = 7.03$, $p < .05$, $MS_e = 20{,}034$; $F_2(1, 16) = 4.60$, $p < .05$, $MS_e = 26{,}510$; and complementizer presence, $F_1(1, 20) = 6.71$, $p < .01$, $MS_e = 21{,}748$; $F_2(1, 16) = 6.41$, $p < .05$, $MS_e = 16{,}344$; whereas the interaction between these factors did not reach significance, $F_1(1, 20) = 2.91$, $p = .10$, $MS_e = 16{,}790$; $F_2(1, 16) = 1.94$, $MS_e = 21{,}090$.

At the final verb phrase region, although there was a clear interaction between verb type and complementizer presence, $F_1(1, 20) = 12.84$, $p < .01$, $MS_e = 19{,}999$; $F_2(1, 16) = 6.29$, $p < .01$, $MS_e = 32{,}413$, simple effects revealed an effect of complementizer presence for both the NP-bias verbs, $F_1(1, 20) = 40.42$, $p < .01$, $MS_e = 23{,}344$; $F_2(1, 16) = 16.55$, $p < .01$, $MS_e = 45{,}850$, and the S-bias verbs, $F_1(1, 20) = 5.92$, $p < .05$, $MS_e = 10{,}948$; $F_2(1, 16) = 4.60$, $p < .05$, $MS_e = 11{,}740$.

Correlations with that preference. Reading times for S-bias verbs were somewhat longer at both the noun phrase and the verb phrase in the sentences without a complementizer in comparison with the sentences with a complementizer. We again examined the correlations between the size of the complementizer effect and the strength of *that* preference for the S-bias verbs (see Table 5). We did not compute correlations with the NP-bias sentences without a complementizer because both the noun phrase and the verb phrase regions contain long second-pass reading times that are due to the garden-path found in this condition. As in Experiments 1 and 2, there was a correlation with degree of *that* preference, no correlation with strength of verb bias, and no evidence of a residual complexity effect in the regression equation. Thus, it appears that all minor elevations found in S-bias sentences can be accounted for as a *that*-preference effect.

Table 5
Correlations of Total Reading Time Differences With That *Preference for Experiment 3*

Independent measure	Slope	Intercept	Pearson r	$F(1, 8)$	$p <$
Complementizer effect for sentence-bias sentences at noun phrase region					
% *that*	1.83	−80.0	.604	4.58	.07
Trans(%)	20.4	+12.6	.654	5.97	.05
Complementizer effect for sentence-bias sentences at verb phrase region					
% *that*	1.31	−7.9	.667	6.40	.05
Trans(%)	14.2	+58.3	.703	7.81	.05

Note. Trans(%) = transformed percentages. Intercepts for transformed data do not correspond to 0% *that* preference.

Initial Processing

The total reading times provide clear evidence that readers used verb subcategory information to mediate processing difficulties associated with sentence complements without a complementizer. However, total reading times do not differentiate between initial processing and secondary processing (rereads). Thus, total times do not provide a clear measure of when verb information influences parsing commitments. For this reason, we report several analyses of the eye-movement data that attempt to tap more immediate comprehension processes, including first-pass reading times for each region, the landing site positions for fixations that followed the initial reading of the main verb, and first fixation durations and probabilities for each word in the noun phrase and the disambiguating region.

First-Pass Reading Times

When the reader entered a scoring region, fixation durations were considered to be part of a first-pass reading if (a) the subject had not read the region before and (b) the subject had not already read any of the words beyond that region. A first-pass reading time was obtained by summing the durations of all left-to-right fixations in a region plus any regressions made to other points within that region. When the reader made an eye movement out of a region (either a regressive eye movement to a prior region or a forward movement to a following region), first-pass reading was considered complete for that region (Rayner et al., 1989). Table 6 presents first-pass reading times for the matrix verb, the sentence complement subject NP, and the following three words. As shown in the table, there were little or no differences at either the matrix verb or at the subject of the sentence complement. However, in the final disambiguating region, the NP-bias verb condition showed a considerable increase in reading times for sentences without a complementizer as compared with sentences with a complementizer. The S-bias sentences showed only a small increase for sentences without complementizers. Subject and item means were entered into separate ANOVAs with the same design as the total reading time analyses.

Overall effects. Collapsing across all four scoring regions, the ANOVA revealed no effect of verb type (F_1 and $F_2 < 1$) and a marginal effect of complementizer presence, $F_1(1, 20) = 3.94$, $p < .10$, $MS_e = 10{,}192$; $F_2(1, 16) = 3.59$, $p < .10$, $MS_e = 5{,}808$. The interaction between these two factors was not significant, $F_1(1, 20) = 2.11$, $MS_e = 7{,}493$; $F_2(1, 16) = 1.26$, $MS_e = 8{,}372$. There was an overall effect across scoring regions, $F_1(2, 36) = 120.98$, $p < .01$, $MS_e = 17{,}881$; $F_2(2, 25) = 66.67$, $p < .01$, $MS_e = 27{,}335$. The effect of verb type interacted with region, $F_1(2, 40) = 7.05$, $p < .01$, $MS_e = 5{,}569$; $F_2(2, 32) = 3.53$, $p < .05$, $MS_e = 8{,}966$, as did the effect of complementizer presence, $F_1(2, 40) = 4.33$, $p < .05$, $MS_e = 8{,}563$; $F_2(2, 32) = 5.72$, $p < .01$, $MS_e = 5{,}437$. There was no significant interaction among verb type, complementizer presence, and region, $F_1(2, 32) = 1.03$, $MS_e = 7{,}495$; $F_2(2, 32) = 1.70$, $MS_e = 4{,}358$.

Table 6
Mean First-Pass Reading Times (in ms) for Each Scoring Region for Experiment 3

		Complementizer			
Scoring region	Verb type	Absent	Present	Δ	*M*
"forgot/hoped"	S bias	347	355	−8	351
	NP bias	349	342	+7	346
	Δ	−2	+13	—	—
	M	348	349	—	—
"the solution"	S bias	446	445	+1[a]	446
	NP bias	424	420	+4	422
	Δ	+22[a]	−25	—	—
	M	435	433	—	—
"was in the"	S bias	630	596	+34[a]	613
	NP bias	719	615	+104	667
	Δ	−89	−19	—	—
	M	675	606	—	—

Note. S = sentence; NP = noun phrase.
[a] Difference correlated with lexically specific *that* preferences.

Analysis by region. There were no significant effects or interactions at the matrix verb region (all Fs < 1). There were also no significant effects or interactions at the following noun phrase: For effect of verb type, $F_1(1, 20) = 2.68$, $MS_e = 4{,}916$, $F_2(1, 16) = 1.49$, $MS_e = 4{,}910$; for effect of complementizer, Fs < 1; for interaction, Fs < 1. In the final scoring region, there was a significant effect of verb type, $F_1(1, 20) = 6.89$, $p < .05$, $MS_e = 10{,}086$; $F_2(1, 16) = 4.63$, $p < .05$, $MS_e = 12{,}824$; and a significant effect of complementizer presence, $F_1(1, 20) = 6.76$, $p < .05$, $MS_e = 16{,}871$; $F_2(1, 16) = 8.51$, $p < .01$, $MS_e = 9{,}549$. The interaction between verb type and complementizer presence did not reach significance, $F_1(1, 20) = 2.06$, $MS_e = 14{,}494$; $F_2(1, 16) = 2.61$, $MS_e = 8{,}164$. However, simple effects revealed that for sentences with NP-bias verbs, there was a significant effect of complementizer, $F_1(1, 20) = 6.84$, $p < .05$, $MS_e = 19{,}040$; $F_2(1, 16) = 8.15$, $p < .05$, $MS_e = 11{,}385$, whereas sentences with S-bias verbs showed no effect of complementizer (Fs < 1). Also, first-pass reading times showed no reliable effects of verb type in the complementizer-present stimuli (Fs < 1).

Correlations with that *preference.* First-pass reading times for S-bias verbs did not show significant elevations at the noun phrase or the verb phrase in the sentences without a complementizer as compared with the sentences with a complementizer. Nonetheless, we again examined the correlations between size of the complementizer effect and the strength of that preference for the S-bias verbs (see Table 7). The difference between the S-bias and NP-bias sentences without a complementizer (i.e., the verb-type effect) was not tested for the verb phrase region because NP-bias sentences are elevated due to a syntactic misanalysis. As in Experiments 1 and 2, there was a correlation with the degree of *that* preference, no correlation with strength of verb bias, and no evidence of a residual complementizer effect in the regression equation. Thus, the small differences for S-bias verbs were again due to a complementizer preference effect.

Summary of first-pass reading times. The first-pass reading times indicated that early processing was influenced by verb information. At the disambiguating verb phrase region of the sentence complement, readers showed a reliable increase in reading times in NP-bias sentences when the complementizer was not present, suggesting that they initially interpreted the earlier noun phrase as a direct object. For S-bias sentences, however, subjects had little difficulty reading the final region when the complementizer was not present. Although the interaction between verb type and complementizer presence did not reach significance at the verb phrase, this lack of a reliable interaction was most likely due to the small complementizer effect for S-bias verbs. However, this effect correlated with the degree of *that* preference, and the relation revealed no residual complementizer effect at the zero intercept.

The first-pass reading times at the noun phrase, however, were missing a crucial result found in the self-paced reading study. The self-paced reading revealed an early complementizer effect at the noun phrase for the S-bias sentences, which was not detected by the first-pass analysis. However, the first-pass reading time difference between S-bias sentences with and without a complementizer again correlated with *that* preference. The presence of this correlation strongly suggests that the no-difference finding in the average reading times is not simply the result of variability from an insensitive measure. Rather, it appears either that the first-pass reading times for the S-bias sentences without a complementizer were systematically decreased or that the first-pass reading times for the baseline sentences (sentences with a complementizer) were systematically elevated. In fact, it appears that the latter proposal is correct. Additional analyses, described later, clearly reveal that the lack of effects at the noun phrase are due to preview effects common to reading short function words (e.g., *that, the, was*). In particular, we demonstrate that reading times to the postverbal noun phrase were artificially elevated for all sentences without a complementizer because

Table 7
Correlations of First-Pass Reading Time Differences With That *Preference for Experiment 3*

Independent measure	Slope	Intercept	Pearson *r*	*F*(1, 8)	*p* <
Complementizer effect for sentence-bias sentences at noun phrase region					
% that	1.07	−67.4	.402	1.55	—
Trans(%)	17.1	−17.07	.628	5.21	.05
Verb-type effect for sentences without a complementizer at noun phrase region					
% that	1.16	−43.1	.529	3.12	—
Trans(%)	14.3	+14.4	.638	5.49	.05
Complementizer effect for sentence-bias sentences at verb phrase region					
% that	1.83	−79.9	.604	4.59	.07
Trans(%)	20.4	+12.6	.654	5.97	.05

Note. Trans(%) = transformed percentages. Intercepts for transformed data do not correspond to 0% *that* preference.

of basic changes in first-pass eye-movement patterns resulting from skipping the complementizer *that.*

Landing Site Positions of Initial Fixations After the Verb

There are several differences between natural reading (in eyetracking) and self-paced reading (Burgess, 1991; Ferreira & Clifton, 1986; Ferreira & Henderson, 1990; Just, Carpenter, & Woolley, 1982). Of primary interest is that readers in eyetracking studies often skip short function words (e.g., *the, that by, was*; Just & Carpenter, 1980; Rayner & McConkie, 1976; Rayner & Pollatsek, 1987). Presumably, the reader has recognized or can predict the function word while reading the previous word and does not need to centrally foveate it. When two function words appear in a row, it is likely that the second of the two will have a higher than normal probability of being foveated (i.e., the first function word is skipped, whereas the second is fixated).

In our baseline conditions, the insertion of a *that* resulted in the presence of two short function words in a row (". . . that the . . ."). Indeed, an analysis of the fixation data after the matrix verb revealed that the inclusion of a complementizer had effects on the probability with which *the* was fixated. Without the complementizer (e.g., "the student hoped the solution . . ."), the determiner was typically skipped. When the complementizer was present (e.g., "the student hoped that the solution . . ."), *that* was often skipped and the *the* was frequently fixated. This is of critical importance because it means that we were comparing first-pass reading times to noun phrase regions (e.g., "the solution") that had different fixation patterns.

To illustrate this, we collected the landing site position of the two forward fixations after any first-pass reading of the matrix verb. These fixations were typically the only fixations contributing to first-pass reading times at the NP (if the fixation was in the region). Figure 3 shows histograms of the landing site positions of these forward fixations after the matrix verb relative to the right-hand boundary of the verb (i.e., the last letter of the verb). The top panel of Figure 3 shows these data when the complementizer was absent, and the bottom panel shows these data when the complementizer was present. (An analysis that subdivided the data on the basis of verb type showed no differences between S-bias and NP-bias verbs.) As one can see, there was little difference in the landing site positions for either condition. However, the vertical lines define the average word boundaries (a noun was on average 7.8 characters long). The insertion of a *that* in 3b offsets the character positions of each scoring region by exactly 5 characters (space + *that*). Thus, subjects typically fixated on the head noun of the noun phrase when the complementizer was absent but fixated on the determiner when the complementizer was present.

Two ANOVAs were conducted on these data. One analysis was done on the character position landing site data as shown in the figure. As expected, there was no effect of complementizer presence or verb type for either fixation (Fs < 1). An identical analysis was done using character position with respect to the leftmost boundary of the NP region. These data

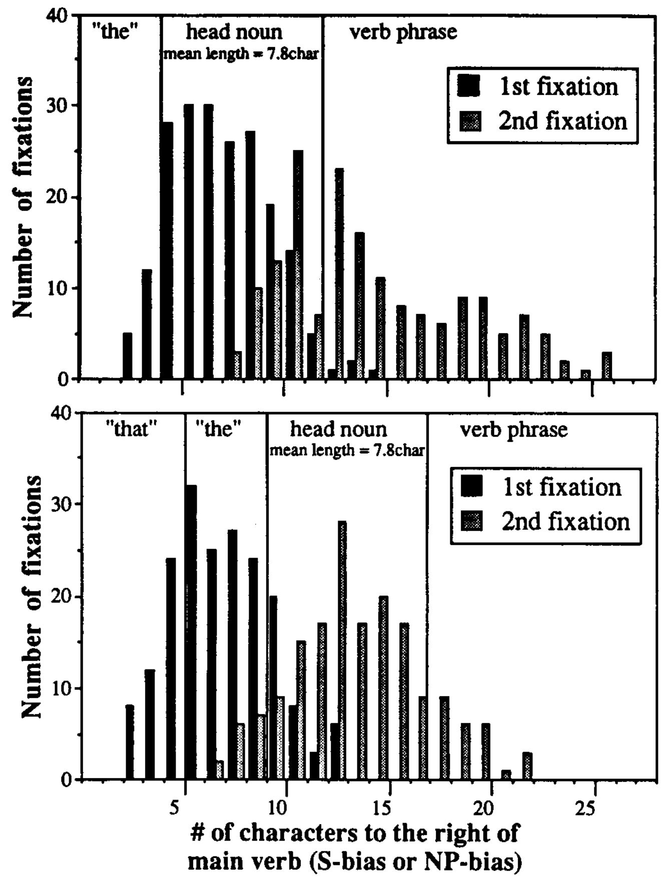

Figure 3. Number of first two forward eye-movement landing sites after first-pass reading of matrix verb as a function of character position. (The top panel shows sentences without the complementizer *that*; the bottom panel shows sentences with the complementizer *that*; char = character; S = sentence; NP = noun phrase.)

were the same, except that when the complementizer was present, five character positions were deducted from the landing site. As one might expect, there was a significant effect of complementizer presence for both fixations: first fixation, $F_1(1, 20) = 494.56$, $p < .01$, $MS_e = 1.203$; $F_2(1, 16) = 399.43$, $p < .01$, $MS_e = 1.272$; second fixation, $F_1(1, 20) = 96.54$, $p < .01$, $MS_e = 8.316$; $F_2(1, 16) = 174.41$, $p < .01$, $MS_e = 3.977$; there was no effect of verb type (Fs < 1). By the third forward fixation (not shown here), average landing sites began to readjust so that there was little difference in the position of the third fixation for both sentence types.

This analysis demonstrates that although fixation character positions did not differ between the test items and their baselines, they did differ with respect to the critical scoring region boundaries. Thus, the probability of initially landing on one word or another within the two-word scoring region of the noun phrase was influenced by whether the complementizer was present.This pattern of forward eye movements makes it extremely likely that first-pass reading times in this region were artificially elevated for sentences with a complementizer. The initial fixation in these conditions tended to be on the less informative determiner, forcing either a longer than normal reading time to recognize the head noun parafoveally or a second fixation in the region to fully foveate the noun. Thus, these changes in fixation probabilities elevated first-pass reading times on the entire noun phrase when the complementizer was present, effectively masking any elevations in processing load due to the absence of the complementizer. Despite these elevations in the baseline, correlations on this nonsignificant complementizer effect at the noun phrase still revealed a *that* preference effect for S-bias verbs.

First Fixation Durations and Comparisons With Ferreira and Henderson (1990)

Ferreira and Henderson (1990) did not report first-pass analyses. Instead, they reported the duration of the first fixation for each word. First fixation duration is the duration of the initial fixation of a first-pass reading of a region. Thus, any first-pass refixations in a region do not contribute to this measure. In order to permit a direct comparison to Ferreira and Henderson's results, we will also report first fixation duration data.

For convenience, Ferreira and Henderson's (1990) mean first fixation durations for the three words following the matrix verb are presented in Table 8. Recall that these are the ambiguous noun (1), the disambiguating verb (2), and the next word (3) in Example 7.

Bill hoped/wrote (that) Jill arrived safely today.
1 2 3 (Example 7)

There was a main effect of complementizer presence at the disambiguating verb (Position 2). Fixation durations at this position were longer for sentences without a complementizer than for sentences with a complementizer, regardless of verb type. No reliable effects or interactions were found in the first or third positions.

Table 9 reports mean first fixation durations for the five words following the matrix verb in our study. These words were the determiner (1), the head noun (2), the disambiguating word (3), and the next two words (4 and 5).

The student hoped/forgot (that) the solution was in the back of the book. 1 2 3 4 5
(Example 8)

The means showed an effect of complementizer presence at the head noun (Word Position 2). Sentences without a complementizer were slower than sentences with a complementizer. Recall that this effect was not found in the first-pass analyses of the entire noun phrase region. However, the fixations durations at the verb phrase region (Word Positions 3, 4, and 5) revealed a pattern very consistent with the first-pass analysis. Fixation durations for NP-bias sentences without a complementizer were longer than those for the other three sentence types. ANOVAs at each word position revealed only a reliable effect of complementizer presence at the head noun, $F_1(1, 20) = 12.77$, $p < .01$, $MS_e = 1{,}382$; $F_2(1, 16) = 24.39$, $p < .01$, $MS_e = 553$. No other reliable effects or interactions were found. However, at the third position (the disambiguating word), there was a marginal effect of complementizer, $F_1(1, 20) = 4.27$, $p < .10$, $MS_e = 2{,}949$; $F_2(1, 16) = 3.92$, $p < .10$, $MS_e = 2{,}387$. This effect was carried by an effect in the NP-bias verbs, $F_1(1, 20) = 3.92$, $p < .10$, $MS_e = 3{,}907$; $F_2(1, 16) = 4.12$, $p < .10$, $MS_e = 2{,}182$; but not the S-bias verbs (Fs < 1).

Statistically, then, the first fixation pattern in our study was identical to that of Ferreira and Henderson (1990). In both studies, the second word after the matrix verb showed a main effect of complementizer. Fixation durations at this position were longer for sentences without a complementizer than for sentences with a complementizer, regardless of verb type.

Table 8
Mean First Fixation Duration (in ms) From Ferreira and Henderson (1990) for the Noun, the Disambiguating Sentence Complement Verb, and the Next Word

		Complementizer			
Word position	Verb type	Absent	Present	Δ	*M*
Noun	S bias	214	208	+6	211
	NP bias	217	200	+17	209
	M	216	204	—	—
Disambiguating SC verb	S bias	230	200	+30	215
	NP bias	215	201	+14	208
	M	223	201	—	—
Next word	S bias	321	288	+33	305
	NP bias	308	302	+6	305
	M	314	295	—	—

Note. S = sentence; NP = noun phrase; SC = sentence complement.

Table 9
Mean First Fixation Duration (in ms) for the Determiner, the Head Noun, the Disambiguating Sentence Complement Verb, and the Next Two Words for Experiment 3

		Complementizer			
Word position	Verb type	Absent	Present	Δ	*M*
Determiner	S bias	240	237	+3	239
	NP bias	240	244	−4	242
	M	240	241	—	—
Head noun	S bias	279	251	+28	265
	NP bias	286	259	+27	273
	M	283	255	—	—
Disambiguating SC verb	S bias	263	253	+10	258
	NP bias	281	246	+35	264
	M	272	250	—	—
Next word	S bias	272	264	+6	268
	NP bias	287	267	+20	277
	M	278	266	—	—
Next word	S bias	264	260	+4	262
	NP bias	287	272	+15	280
	M	276	266	—	—

Note. S = sentence; NP = noun phrase; SC = sentence complement.

This similarity suggests that the Ferreira and Henderson (1990) results and the present results are not as dramatically different as one might expect. However, because our main effect of complementizer occurred prior to the disambiguating word (on the head noun) rather than on the disambiguating verb, the results suggest that the elevations in first fixation durations for sentences without a complementizer in both studies were not due to syntactic misanalysis.

Three questions are raised by the first fixation results in our experiment. First, why were first fixation durations in the verb phrase region too noisy to find any reliable differences? Second, why did first fixation durations differ for the head noun in the complementizer-present and -absent conditions? Third, why did first-pass reading times at the noun phrase not show a similar elevation? An analysis of the probability of fixating on each word provided a plausible answer to each of these questions.

As mentioned earlier, it is well established in the literature that although the majority of words in a sentence are fixated, many words are skipped (Just & Carpenter, 1980; Rayner & McConkie, 1976; see also Rayner & Pollatsek, 1987). Shorter words are less likely to be fixated (Rayner & McConkie, 1976). First fixation durations for a word are based on only those trials in which the subject fixated on the word without having already fixated on any other words further along in the sentence. Table 10 presents the probability of a first fixation for each of our critical word's positions.

Clearly, certain words tended to be skipped, especially the determiner and the disambiguating word, which was typically a *be* verb or modal. The probability of fixating on these words is consistent with fixation probability data reported by Rayner and McConkie (1976) and Just and Carpenter (1980). Thus, it should be clear why the only reliable effect for first fixation durations occurred at the head noun of the noun phrase. It was the only position that subjects consistently fixated. The probabilities at all other word positions were low enough that subject and item cell means represented relatively few observations, and often represented different sets of subjects or different sets of items. Thus, the means will be relatively noisy at these positions. In fact, the probability of a first-pass fixation on a word was sometimes low enough that subject and item cell means had no data. In other words, either a subject consistently skipped a word in a given subject condition, or all subjects consistently skipped a word in a given item condition. Thus, in order to perform the prior first fixation duration ANOVAs, certain item cell means and certain subject cell means had to be replaced by an estimated value.[5] For subject means, the following percentage of cells had to be estimated: 10% at the determiner, 1% for the head noun, 8.3% at the disambiguating modal. For the item means the percentages were 6% at the disambiguating modal and 5% at the final word. Missing data are less of a problem with larger scoring regions. For example, the probability of a first-pass reading on each trial for the scoring regions in the analyses we reported earlier was close to 1.0.

Now consider the second question, namely, why was there an effect of the complementizer on the initial fixations to the head noun? As would be expected by the landing site analyses reported earlier, the probability of a reader fixating on the determiner (shown in Table 10) was considerably higher when the complementizer was present compared with when it was absent, $F_1(1, 20) = 6.47, p < .05, MS_e = 0.1568$; $F_2(1, 16) = 21.98, p < .01, MS_e = 0.0389$. When *that* was present, subjects tended to skip *that* and land on *the* and then move on to the head noun. When *that* was absent, subjects often skipped *the* and landed directly on the head noun. As a consequence, subjects were much more likely to fixate on the word preceding the noun when there was a complementizer present, permitting them to have a clear preview advantage when they moved to the noun. Inhoff and Rayner (1986), Lima (1987), and Pollatsek, Rayner, and Bolota (1986) have all demonstrated that the first fixation on a word is shorter when visual information about the word is available parafoveally on the prior fixation than when the visual information is not available. (See Rayner & Pollatsek, 1987, for a complete review.) Thus, the complementizer effect at the head noun is likely to be due to a preview effect.

If the complementizer effect at the noun was in fact due to a preview effect (or some other low-level source), then we would not expect it to correlate with any of the variables measured in the completion norms. In fact, this was the case. The complementizer effect at the noun in both the S-bias and

Table 10
The Probability of a First-Pass Reading for the Determiner, the Head Noun, the Disambiguating Sentence Complement Verb, and the Next Two Words for Experiment 3

Word position	Verb type	Complementizer: Absent	Complementizer: Present	Δ	*M*
Determiner	S bias	0.38	0.60	−0.22	0.49
	NP bias	0.45	0.64	−0.19	0.55
	M	0.42	0.62	—	—
Head noun	S bias	0.97	0.96	+0.01	0.97
	NP bias	0.91	0.85	+0.06	0.88
	M	0.94	0.91	—	—
Disambiguating SC verb	S bias	0.46	0.37	+0.09	0.42
	NP bias	0.54	0.53	+0.01	0.54
	M	0.50	0.45	—	—
Next word	S bias	0.77	0.75	+0.02	0.76
	NP bias	0.78	0.79	−0.01	0.79
	M	0.78	0.77	—	—
Next word	S bias	0.69	0.74	−0.05	0.72
	NP bias	0.70	0.69	+0.01	0.70
	M	0.70	0.72	—	—

Note. S = sentence; NP = noun phrase; SC = sentence complement.

[5] Missing data were estimated using the stepwise regression estimation routine found in the BMDP statistical package (subroutine pam). Estimations of missing subject and item cell means were based on correlations with all other means, including each subject's or item's overall mean, and the overall mean within a given position. It should be noted that subject and item means did not change much when missing data were replaced.

NP-bias sentences did not correlate with the percentage of NP, S, or *that* completions or any differences or transformations. Thus, it appears that these effects do not arise from parsing considerations.

Although Ferreira and Henderson (1990) did not report first fixation probabilities, it is likely that the complementizer effect at the verb in their experiment was also due to landing site differences.[6] When the complementizer was absent, subjects may have tended to skip the noun and land directly on the disambiguating verb, whereas when the complementizer was present, subjects may have been more prone to skip the *that*, land on the noun and then the verb, providing a preview advantage for the verb. Ferreira and Henderson's nouns were relatively short (averaging 4.7 characters). Although we are unaware of a study reporting fixation probabilities for different lengths of content words alone, Rayner and McConkie (1976) found that, in general, words under 6 characters in length have less than a 0.6 probability of fixation. So, if the probability of fixating on the noun differed in the complementizer-absent and -present conditions in the Ferreira and Henderson study, they are likely to have found the same pattern of differences at the verb that we found at the noun.

Finally, the third question concerning our data was why no complementizer effect was seen for the first-pass analyses of the entire noun phrase region. Although first fixations were faster on the head noun when the complementizer was absent compared with when it was present, the fixation probabilities revealed that these faster fixations were also accompanied by a greater probability of having a fixation on the prior determiner. Thus, overall, these shorter fixations were accompanied by more fixations on the determiner, making first-pass reading times in these conditions slightly longer, and effectively masking the first fixation difference. To demonstrate this informally, we multiplied the probabilities of a fixation at the determiner and the noun with their respective first fixation durations, and then added these products together for each condition. The results revealed no differences between the complementizer-present and complementizer-absent conditions (NP bias without complementizer: 376 ms; NP bias with complementizer: 376 ms; S bias without complementizer: 362 ms; S bias with complementizer: 383 ms).

For the most part, the analysis of the first fixation data revealed patterns that were consistent with both the first-pass data and the landing site data. The only discrepancy, a complementizer effect at the head noun, was most likely due to eye-movement landing site differences. A similar effect is likely to have occurred in the Ferreira and Henderson (1990) study, resulting in first fixation elevations that appeared to be due to a syntactic misanalysis but were actually due to changes in the probability of the fixating on different words.

Reprocessing (Rereads)

Regressive eye-movement pattern. Eye-movement patterns from our study also indicated that sentences without a complementizer had large reanalysis effects (rereads) when the verb was NP-bias versus when it was S-bias. For NP-bias sentences without a complementizer, 38% of first-pass readings of the final word of the disambiguating verb

Table 11
Mean Second-Pass Reading Times (in ms) for Each Scoring Region for Experiment 3

Scoring region	Verb type	Complementizer Absent	Complementizer Present	Δ	*M*
"The student"	S bias	78	87	−9	83
	NP bias	149	70	+79	110
	M	114	79	—	—
"forgot/hoped"	S bias	93	78	+15	83
	NP bias	205	91	+114	148
	M	149	85	—	—
"the solution"	S bias	111	78	+33	95
	NP bias	254	136	+118	195
	M	183	107	—	—
"was in the"	S bias	131	91	+40	111
	NP bias	354	178	+176	266
	M	243	135	—	—

Note. S = sentence; NP = noun phrase.

phrase region ended with a regressive eye movement as compared with 19% when the sentence contained a complementizer. For S-bias sentences without a complementizer, 16% of the first-pass readings ended with a regressive eye movement as compared with 15% when the sentence contained a complementizer. Such a pattern suggests that a garden-path occurred only in the NP-bias sentences without a complementizer.

Second-pass reading times. Table 11 presents second-pass reading times in milliseconds for all four regions. Second-pass reading times reflect any rereads of these regions. As seen in the table, NP-bias sentences without a complementizer showed large elevations in second-pass reading times with respect to the other three conditions. Subject and item means were entered into separate ANOVAs with four factors: list (four lists) or item group (four groups); region (subject NP, matrix verb, sentence complement subject NP, and sentence complement verb [three words]); verb type (S bias and NP bias); and complementizer (present and absent). We will report overall effects and interactions and then effects at each scoring region.

When collapsing across all four scoring regions, the ANOVA revealed a significant interaction between verb type and complementizer presence, $F_1(1, 20) = 7.96$, $p < .05$, $MS_e = 31{,}255$; $F_2(1, 16) = 7.58$, $p < .05$, $MS_e = 33{,}469$.

[6] It should be noted that for unrelated reasons Ferreira and Henderson (1990) embedded a contingent display manipulation into their eye-movement study (see Henderson & Ferreira, 1990). On two thirds of the experimental trials, a nonword was presented parafoveally (the next word over) when subjects fixated on the disambiguating verb. This nonword rapidly changed into the appropriate word while subjects moved their eyes to foveate the nonword position. Henderson and Ferreira (1990) noted that subjects occasionally volunteered that they had detected a display change. It is conceivable that the detection of display changes might have influenced overall fixation patterns.

In addition, there were significant effects of verb type, $F_1(1, 20) = 19.83, p < .01, MS_e = 35{,}999$; $F_2(1, 16) = 8.79, p < .01, MS_e = 62{,}677$; and complementizer presence, $F_1(1, 20) = 20.46, p < .01, MS_e = 23{,}477$; $F_2(1, 16) = 24.18, p < .01, MS_e = 18{,}425$. Simple effects revealed a significant effect of complementizer presence for the NP-bias sentences, $F_1(1, 20) = 18.55, p < .01, MS_e = 38{,}281$; $F_2(1, 16) = 20.06, p < .01, MS_e = 34{,}190$; but not the S-bias sentences, $F_1(1, 20) = 1.15, MS_e = 16{,}451$; $F_2(1, 16) = 0.76, MS_e = 17{,}704$. In addition, there was a significant effect of verb type for sentences that did not contain a complementizer, $F_1(1, 20) = 15.75, p < .01, MS_e = 57{,}321$; $F_2(1, 16) = 11.01, p < .01, MS_e = 70{,}539$. Sentences containing a complementizer showed an effect of verb type in the subject analyses but not in the item analyses, $F_1(1, 20) = 6.03, p < .01, MS_e = 9{,}933$; $F_2(1, 16) = 1.11, MS_e = 25{,}608$. There was a significant effect of scoring region, $F_1(3, 36) = 11.06, p < .01, MS_e = 11{,}811$; $F_2(3, 54) = 14.46, p < .01, MS_e = 10{,}660$. In addition, the effect of verb type interacted with scoring region, $F_1(3, 43) = 8.24, p < .01, MS_e = 7{,}748$; $F_2(3, 57) = 11.91, p < .01, MS_e = 6{,}028$; and the effect of structure interacted with scoring region, $F_1(3, 59) = 3.47, p < .05, MS_e = 6{,}318$; $F_2(3, 48) = 3.25, p < .01, MS_e = 5{,}809$.

Analysis by region. Separate analyses were conducted for each scoring region. To conserve space, the same basic effects obtained at each region: an interaction between verb type and complementizer presence, overall effects of both verb type and complementizer, an effect of complementizer presence for sentences with NP-bias verbs but not with S-bias verbs, and an effect of verb type for sentences without a complementizer. The only effect that varied across position was an effect of verb type for sentences containing complementizers. At the first two regions, there was no effect ($Fs < 1$). However, at the final two regions there was an effect but only in the subject analyses: At the NP, $F_1(1, 20) = 8.41, p < .01, MS_e = 4{,}779$; $F_2(1, 16) = 2.25, MS_e = 10{,}330$; at the second verb, $F_1(1, 20) = 9.81, p < .01, MS_e = 9{,}220$; $F_2(1, 16) = 3.46, p < .10, MS_e = 21{,}479$.

Discussion

The results demonstrated clear and immediate effects of verb subcategorization. Consider first the results for the sentences with NP-bias verbs. These sentences showed large reanalysis effects when the complementizer was absent. First-pass reading times at the disambiguating verb phrase were longer for sentences without a complementizer than for sentences with a complementizer. Near the end of the verb phrase, readers were more likely to make a regressive eye movement for the sentences without complementizers. In addition, second-pass and total reading times for sentences without a complementizer were elevated in comparison with all other sentence types. All of these results indicate that subjects initially incorporated the noun phrase after an NP-bias verb as the direct object of the verb. The subsequent verb phrase then forced a reanalysis.

The S-bias sentences, on the other hand, showed no evidence of a misanalysis effect. First-pass reading times at the noun phrase and the following verb phrase regions were not reliably longer for sentences without a complementizer as compared with those with a complementizer. Regressive eye movements at the verb phrase were equally likely for sentences with and without a complementizer. Moreover, second-pass reading times were not reliably different. The only reliable complementizer effect occurred for total reading times at the verb phrase. This effect and the nonsignificant effects in first-pass reading times at the noun phrase and the verb phrase all correlated with the *that* preference for individual verbs. As in Experiment 2, the regression equations did not reveal the residual reanalysis effect that would be predicted by lexical filtering models.

Along with the evidence concerning the use of verb information, the results of the present study also have important methodological implications for eye-movement studies. An analysis of landing site probabilities revealed that the insertion of a short function word (*that*) altered the probabilities of landing on particular words within the following scoring region. This result is likely to have direct bearing on other eye-movement studies of parsing. Many parsing studies compare first-pass reading times across scoring regions with the same linguistic content but with different character positions. Thus, as in our study, scoring regions are typically offset because of the insertion of one or two syntactically disambiguating function words prior to the critical scoring regions. Under these conditions, comparisons of ambiguous and unambiguous structures can both mask real effects and introduce spurious differences. In the present study, we have argued that preview advantages arising from landing site differences on the determiner decreased first fixation durations at the head noun when it followed a complementizer. Moreover, the same landing site differences resulted in *increased* first-pass reading times to the entire noun phrase when the complementizer was present, because fixations on the head noun were typically accompanied by a prior fixation on the determiner. Both of these fixations would have contributed to the first-pass analysis of the noun phrase.

General Discussion

The research reported here provided clear answers to the three questions that we outlined earlier. First, subcategorization information becomes available almost immediately after a verb is recognized. Experiment 1 demonstrated that subcategorization information was available rapidly enough to influence integration effects in cross-modal naming when the visual target immediately followed the verb.

Second, there is processing difficulty associated with *that*-less sentence complements that is not due to syntactic misanalysis. Pronouns that unambiguously determine a sentence complement reading (e.g., *he*) were more difficult to name when preceded by an S-bias sentence fragment without a complementizer as compared with an S-bias sentence fragment with a complementizer. This effect cannot be attributed to a temporary syntactic misanalysis for two reasons: First, the results with *him* demonstrated that subcategorization information is available, and second, the pronoun *he* is unambiguously a subject pronoun. Moreover, correlations between the completion norms and the complementizer effect indicated that the effect depended on the degree to which the verb was preferably followed by sentence complement containing a complementizer.

Third, the subcategorization properties of the verb immediately affect the syntactic analysis of a noun phrase that would otherwise be ambiguous. Experiments 2 and 3 demonstrated clear syntactic misanalysis effects when a noun phrase that was a plausible object of an NP-bias verb turned out instead to be the subject of a sentence complement. However, no misanalysis effects obtained when the same noun phrase followed an S-bias verb. Instead, reading times to the noun phrase were elevated in comparison with sentences in which the noun phrase was preceded by a complementizer. This complementizer effect was again correlated with the degree to which the verb prefers to be used with a complementizer when it occurs in a sentence complement construction. Finally, the eye-tracking data also showed small elevations in reading times at the verb phrase for S-bias verbs. These effects, like those at the noun phrase, were correlated with complementizer preference.

This set of results is clearly problematic for lexical filtering models. In the model proposed by Ferreira and Henderson (1991), lexically specific information is used to guide syntactic misanalysis only after the parser encounters syntactic information that is inconsistent with the initial parse. Our results are clearly inconsistent with this prediction. Subcategorization information is accessed as soon as a verb is encountered, and it has immediate effects on the processing of information that follows the verb. Moreover, no syntactic misanalysis occurs when readers encounter information that is consistent with the subcategorization properties of the verb, but would have been inconsistent with an analysis based on major category information and attachment strategies.

Models in which lexical filtering occurs more rapidly also run into serious problems (Frazier 1987, 1989; Mitchell, 1989). One might attempt to explain our data by proposing that a noun phrase following a sentence complement verb is initially parsed as the object of the verb, with reanalysis taking place within the 400- to 600-ms window that it takes readers to process a two-word noun phrase. This would predict elevated reading times to noun phrases that follow verbs that are strongly biased against an NP complement but no subsequent misanalysis effect. Although this story superficially describes the data, it runs into serious empirical and theoretical problems.

The first empirical problem comes from our finding that the processing of the subject of a sentence complement (in the absence of a complementizer) was more difficult than the processing of a noun phrase complement, even when the possibility of syntactic misanalysis did not exist (i.e., when the complement was a case-marked pronoun). The second problem comes from the, finding that, for S-bias verbs, the magnitude of the complementizer effect (the difference in processing times to noun phrases when there was not a complementizer compared with when there was a complementizer) correlated with the degree to which the verb preferred to be followed by a complementizer but not with the strength of the subcategorization bias. Moreover, the regression equations with both unambiguous noun phrases (Experiment 1) and potentially ambiguous noun phrases (Experiments 2 and 3) showed no hint of the residual complementizer effect that is required by the lexical filtering hypothesis. Given these facts, a rapid revision hypothesis is untenable.

The theoretical difficulties for lexical filtering models are equally serious. There are two reasons why a language-processing system might initially ignore lexically specific syntactic constraints. The first reason is that lexically specific information might be accessed too slowly to be reliably used by the system when it is making initial commitments. However, this is clearly not the case given the data that we and others have presented. The second reason is that ignoring lexically specific information might increase the speed and efficiency of the system by allowing the system to build a structure more rapidly, thereby reducing memory load (Frazier, 1989). However, this argument is valid only for a serial parser in which complete commitments either are based on major category information (and thus can be made immediately) or must await definitive evidence about subcategorization information (which can be delayed for several words or even phrases). Recent results suggest that this strong serial assumption is unlikely to be correct (Altmann & Steedman, 1988; Gorrell, 1989, 1991; MacDonald, Just, & Carpenter, 1992; Ni & Crain, 1990; Trueswell et al., 1992). Moreover, it is hard to defend the proposal that building and immediately revising a structure places fewer demands on working memory than building a structure that is consistent with the relevant linguistic information, especially when that information has just been accessed.

The results presented here complement recent studies finding that other aspects of verb-based information are also immediately accessed and used in sentence processing (for a recent review see Boland & Tanenhaus, 1991). These studies converge on a view in which recognition of a verb makes available combinatory syntactic and semantic information that allows the processing system to make partial commitments while taking into account relevant semantic, syntactic, and discourse-based information (Carlson & Tanenhaus, 1988; MacDonald, 1992; Marslen-Wilson, Brown, & Tyler, 1988; Tanenhaus, Boland, Mauner, & Carlson, in press; Tanenhaus & Carlson, 1989; Tanenhaus, Carlson, & Trueswell, 1989; Tanenhaus, Garnsey, & Boland, 1991; Tyler, 1989). Empirical results supporting this view include evidence that the semantic fit of potential arguments is used in syntactic ambiguity resolution with relative clauses (Burgess, 1991; MacDonald, 1992; Pearlmutter & MacDonald, 1992; Trueswell et al., 1992); evidence that verb-based control information is used immediately (Boland, Tanenhaus, & Garnsey, 1990); and evidence that the semantic fit between a verb and potential arguments is used in filler-gap assignment (Tanenhaus, Boland, Garnsey, & Carlson, 1989). Results such as these all depend to some degree on the availability of verb-specific syntactic constraints.

The fact that verb subcategorization information is immediately accessed and used does not, however, mean that all syntactic commitments are determined by lexically specific information as opposed to information based on syntactic categories. For example, in constraint-based approaches to parsing, the relative strength of category effects and subcategory effects in different environments will depend on which type of information is more reliable. Thus, we would expect to find certain environments in which verb-specific constraints have weak or delayed effects and other environments in which they would have immediate effects. This would be consistent with the statistical tuning hypothesis advanced by Mitchell and Cuetos (1991). The *that*-preference effect that we report is further evidence that the language-processing system is subtly tuned to lexically specific co-occurrences. As we mentioned earlier, this type of effect is naturally accommodated within constraint-based frameworks. The presence of such an effect suggests that it will be fruitful to explore how lexical co-occurrence patterns affect the parsing of other structures. It will also be important to explore explanations for why such patterns might occur in the language, such as the relative frequency of a verb, the semantic characteristics of the verb, the propositional content of the complement, and so on. (See Elsness, 1984, for some interesting observations.) Finally, it will be important to determine whether *that*-preference effects also occur with less strongly based sentence complement verbs.

The current results have several significant methodological implications for empirical investigations of sentence processing. It will be important for future eye-tracking studies to take into account information about landing sites, especially when making comparisons across structures with different sequences of words. The fixation pattern for identical material can be altered dramatically by the insertion of a word or two. This can lead to real differences being masked, but can also introduce spurious differences. (In fact, both of these effects were observed in Experiment 3.) Other reading methodologies, in particular, self-paced reading with single-word presentation, have different albeit related problems, because subjects are forced to fixate each word and do not have the advantage of parafoveal information.

Our results also highlight the importance of obtaining normative data for the materials used in sentence-processing experiments. By their very nature, the dimensions measured by norms are continuous rather than discrete. In several recent articles, Pearlmutter and MacDonald (1992; MacDonald, 1992) have argued for treating these variables as continuous and using tools suited to continuous variables, such as regression analyses, in conjunction with on-line measures. Our results clearly support this theoretical and methodological approach.

In addition, our results underscore a simple point about the linking assumption between processing load and underlying comprehension processes that has perhaps been underappreciated in recent work in parsing. Local increases in processing difficulty can be due to a variety of factors, only one of which is syntactic misanalysis. Taking a garden-path explanation as the default will lead one to underestimate the information that the system makes use of during sentence processing and overestimate the amount of syntactic misanalysis that actually occurs.

Finally, the research presented here underscores the value of using multiple methodologies. While each of the methodologies that we used has potential problems of interpretation associated with it, the results from each task helped shed light on the interpretation of the results obtained with the other tasks. Moreover, the fact that similar patterns of results obtained with three different methods makes it unlikely that the results were due to task-specific strategies. In addition, because the tasks are not equally well suited for all problems (e.g., only cross-modal naming can be used to study spoken language processing), it is reassuring to know that the results from each task lead to a similar conclusion.

In sum, we have provided evidence that verb subcategorization information is rapidly accessed and used in syntactic ambiguity resolution. We have also demonstrated a verb-specific co-occurrence effect. Both of these effects are problematic for lexical filtering models, and both are naturally modeled within a constraint-based framework. However, it is important to note that we intentionally selected verbs with extremely strong biases in order to clearly establish whether verb information would be used by the processing system. We also chose nouns that were highly plausible objects for the NP-bias verbs. In addition, for most of these verbs and objects, there was a clear situational shift between the interpretation where the noun phrase was the object (e.g., "accepting an award") and the interpretation where the noun phrase was the subject of a sentence complement ("accepting that the award"). Thus, the results obtained here, namely strong initial commitments consistent with the subcategorization properties of the verb, and clear misanalysis effects when the preferred structure was disconfirmed, could be modeled by any system that is immediately sensitive to lexically specific information and that makes at least provisional on-line commitments to consistent interpretations. In future research it will be important to better understand the nature of the commitments that are typically made during sentence processing as well as how different sources of information are weighted in determining these commitments. Answering these questions will require treating dimensions such as subcategorization preference, semantic fit between an argument and possible argument positions, and situational differences among alternative analyses as continuous variables.

References

Altmann, G. T. M., & Steedman, M. J. (1988). Interaction with context during human sentence processing. *Cognition, 30,* 191–238.

Boland, J. (1991). The use of lexical knowledge in sentence processing (Doctoral dissertation, University of Rochester, 1991). *Dissertation Abstracts International, 52/11B,* 6111.

Boland, J. (in press). The role of verb argument structure in sentence processing: Distinguishing between syntactic and semantic effects. *Journal of Psycholinguistic Research.*

Boland, J., & Tanenhaus, M. K. (1991). The role of lexical representations in sentence processing. In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 331–366). Amsterdam: North-Holland.

Boland, J., Tanenhaus, M. K., & Garnsey, S. M. (1990). Evidence for the immediate use of verb control information in sentence processing. *Journal of Memory and Language, 29,* 413–432.

Britt, M. A., Perfetti, C. A., Garrod, S., & Rayner, K. (1992). Parsing and discourse: Context effects and their limits. *Journal of Memory and Language, 31,* 293–314.

Burgess, C. (1991). Interaction of semantic, syntactic and visual factors in syntactic ambiguity resolution (Doctoral dissertation, University of Rochester, 1991). *Dissertation Abstracts International, 52/02B*, 1098.

Burgess, C., & Tanenhaus, M. K. (1992). *The interaction of semantic and parafoveal information in syntactic ambiguity resolution*. Unpublished manuscript.

Carlson, G. N., & Tanenhaus, M. K. (1988). Thematic roles and language comprehension. In W. Wilkens (Ed.), *Syntax and semantics* (Vol. 21, pp. 263–300). San Diego, CA: Academic Press.

Chomsky, N. (1965). *Aspects of a theory of syntax*. Cambridge, MA: MIT Press.

Clifton, C., Jr., Speer, S., & Abney, S. P. (1991). Parsing arguments: Phrase structure and argument structure as determinants of initial parsing decisions. *Journal of Memory and Language, 30*, 251–271.

Cowart, W. (1987). Evidence for an anaphoric mechanism within syntactic processing: Some reference relations defy semantic and pragmatic considerations. *Memory & Cognition, 15*, 318–331.

Crain, S., & Steedman, M. J. (1985). On not being led up the garden path: The use of context by the psychological parser. In D. Dowty, L. Karttunen, & A. Zwicky (Eds.), *Natural language parsing: Psychological, computational, and theoretical perspectives* (pp. 320–358). Cambridge, England: Cambridge University Press.

Elman, J. L. (1991). Representation and structure in connectionist models. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing: Psycholinguistic and computational perspectives* (pp. 345–382). Cambridge, MA: MIT Press.

Elsness, J. (1984). That or zero? A look at the choice of object clause connective in a corpus of American English. *English Studies, 65*, 519–533.

Ferreira, F., & Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25*, 348–368.

Ferreira, F., & Henderson, J. M. (1990). The use of verb information in syntactic parsing: A comparison of evidence from eye movements and word-by-word self-paced reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 555–568.

Ferreira, F., & Henderson, J. M. (1991). How is verb information used during syntactic processing? In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 305–330). Amsterdam: North-Holland.

Ford, M., Bresnan, J., & Kaplan, R. (1982). A competence based theory of syntactic closure. In J. Bresnan (Ed.), *The mental representation of grammatical relations* (pp. 727–796). Cambridge, MA: MIT Press.

Frazier, L. (1985). Syntactic complexity. In D. Dowty, L. Karttunen, & A. Zwicky (Eds.), *Natural language parsing* (pp. 129–189). Cambridge, England: Cambridge University Press.

Frazier, L. (1987). Sentence processing: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 559–586). Hillsdale, NJ: Erlbaum.

Frazier, L. (1989). Against lexical generation of syntax. In W. D. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 505–528). Cambridge, MA: MIT Press.

Frazier, L., & Clifton, C. (1989). Successive cyclicity in the grammar and the parser. *Language and Cognitive Processes, 4*, 93–126.

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition, 6*, 291–325.

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology, 14*, 178–210.

Gorrell, P. (1989). Establishing the loci of serial and parallel effects in syntactic processing. *Journal of Psycholinguistic Research, 18*, 61–73.

Gorrell, P. (1991). Subcategorization and sentence processing. In R. C. Berwick, S. P. Abney, & C. Tenny (Eds.), *Principle based parsing* (pp. 279–300). Dordrecht, The Netherlands: Kluwer Academic Press.

Hakes, S. D. T. (1972). Effects of reducing complement construction on sentence comprehension. *Journal of Verbal Learning and Verbal Behavior, 11*, 278–286.

Henderson, J. M., & Ferreira, F. (1990). The effects of foveal processing difficulty on the perceptual span in reading: Implications for attention and eye movement control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 417–429.

Hindle, M., & Rooth, M. (1990). Structural ambiguity and lexical relations. In *Proceedings of the 28th annual meeting of the Association of Computational Linguistics* (pp. 229–336). Cambridge, MA: MIT Press.

Holmes, V. M., Stowe, L., & Cupples, L. (1989). Lexical expectations in parsing complement-verb sentences. *Journal of Memory and Language, 28*, 668–689.

Inhoff, A. W., & Rayner, K. (1986). Parafoveal word processing during eye fixations in reading: Effects of word frequency. *Perception & Psychophysics, 40*, 431–439.

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87*, 329–354.

Just, M. A., Carpenter, P. A., & Woolley, J. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General, 111*, 228–238.

Kennedy, A., Murray, W. S., Jennings, F., & Reid, C. (1989). Parsing complements: Comments on the generality of the principle of minimal attachment. *Language and Cognitive Processing, Parsing and Interpretation, 4*, 21–49.

Lima, S. D. (1987). Morphological analysis in sentence reading. *Journal of Memory and Language, 26*, 84–99.

MacDonald, M. (1992). *Probabilistic constraints and syntactic ambiguity resolution*. Manuscript submitted for publication.

MacDonald, M., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology, 24*, 56–98.

Marslen-Wilson, W. D., Brown, C., & Tyler, L. K. (1988). Lexical representations in language comprehension. *Language and Cognitive Processes, 3*, 1–16.

Marslen-Wilson, W. D., & Tyler, L. K. (1987). Against modularity. In J. Garfield (Ed.), *Modularity in knowledge representations and natural language understanding* (pp. 37–62). Cambridge, MA: MIT Press.

McClelland, J. L., St. John, M., & Taraban, R. (1989). Sentence comprehension: A parallel distributed processing approach. *Language and Cognitive Processes, 4*, 287–336.

Mehler, J., & Carey, P. (1967). Role of surface and base structure in the perception of sentences. *Journal of Verbal Learning and Verbal Behavior, 6*, 335–338.

Mitchell, D. C. (1987). Lexical guidance in human parsing: Locus and processing characteristics. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 601–618). Hillsdale, NJ: Erlbaum.

Mitchell, D. C. (1989). Verb-guidance and other lexical effects in parsing. *Language and Cognitive Processes, 4*, 123–154.

Mitchell, D. C., & Cuetos, F. (1991). *The origins of parsing strategies*. Unpublished manuscript.

Ni, W., & Crain, S. (1990). How to resolve structural ambiguities. *Proceedings to NELS, 20* (2), 414–427.

Pearlmutter, N. J., & MacDonald, M. C. (1992). Plausibility effects in syntactic ambiguity resolution. *Proceedings of the 14th Annual*

Conference of the Cognitive Science Society (pp. 498–503). Hillsdale, NJ: Erlbaum.

Pollatsek, A., Rayner, K., & Bolota, D. A. (1986). Inferences about eye movement control from the perceptual span in reading. *Perception & Psychophysics, 40,* 123–130.

Rayner, K., & Frazier, L. (1987). Parsing temporarily ambiguous complements. *Quarterly Journal of Experimental Psychology, 39A,* 657–673.

Rayner, K., & McConkie, G. W. (1976). What guides a reader's eye movements? *Vision Research, 16,* 829–837.

Rayner, K., & Pollatsek, A. (1987). Eye movements in reading: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 327–362). Hillsdale, NJ: Erlbaum.

Rayner, K., Sereno, S. C., Morris, R. K., Schmauder, A. R., & Clifton, C. (1989). Eye movements and on-line language comprehension processes. *Language and Cognitive Processing, Parsing and Interpretation, 4,* 21–49.

Schmauder, R., Kennison, S., & Clifton, C. (1991). On the conditions necessary for observing argument structure complexity effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 1188–1192.

Shapiro, L. P., Nagel, H. N., & Levin, B. A. (in press). Preferences for a verb's complements and their use in sentence processing. *Journal of Memory and Language.*

Shapiro, L. P., Zurif, E., & Grimshaw, J. (1987). Sentence processing and the mental representation of verbs. *Cognition, 27,* 219–246.

Shapiro, L. P., Zurif, E., & Grimshaw, J. (1989). Verb representation and sentence processing: Contextual impenetrability. *Journal of Psycholinguistic Research, 18,* 223–243.

Spivey-Knowlton, M. J., Trueswell, J. C., & Tanenhaus, M. K. (1992). *Context effects in syntactic ambiguity resolution: Parsing reduced relative clauses.* Manuscript submitted for publication.

Tanenhaus, M. K., Boland, J. E., Garnsey, S. M., & Carlson, G. N. (1989). Lexical structure in parsing long-distance dependencies. *Journal of Psycholinguistic Research, 18,* 37–50.

Tanenhaus, M. K., Boland, J. E., Mauner, G., & Carlson, G. N. (in press). More on combinatory lexical information: Thematic structure in parsing and interpretation. In G. T. M. Altmann (Ed.), *Cognitive models of speech and processing, Volume 2: Psycholinguistic and computational perspectives.* Cambridge, MA: MIT Press.

Tanenhaus, M. K., & Carlson, G. N. (1989). Lexical structure and language comprehension. In W. D. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 529–561). Cambridge, MA: MIT Press.

Tanenhaus, M. K., Carlson, G. N., & Trueswell, J. C. (1989). The role of thematic structures in interpretation and parsing. *Language and Cognitive Processing, Parsing and Interpretation, 4,* 211–234.

Tanenhaus, M. K., Garnsey, S. M., & Boland, J. (1991). Combinatory lexical information and language comprehension. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing: Psycholinguistic and computational perspectives* (pp. 383–408). Cambridge, MA: MIT Press.

Tanenhaus, M. K., & Lucas, M. M. (1987). Context effects in lexical processing. *Cognition, 25,* 213–234.

Taraban, R., & McClelland, J. (1988). Constituent attachment and thematic role assignment in sentence processing: Influences of content-based expectations. *Journal of Memory and Language, 27,* 1–36.

Trueswell, J. C. (1993). (Untitled.) Unpublished doctoral dissertation, Department of Psychology, University of Rochester, Rochester, NY.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1992). *Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution.* Manuscript submitted for publication.

Tyler, L. K. (1989). The role of lexical representations in language comprehension. In W. D. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 439–462). Cambridge, MA: MIT Press.

Tyler, L. K., & Marslen-Wilson, W. D. (1977). The on-line effects of semantic context on syntactic processing. *Journal of Verbal Learning and Verbal Behavior, 16,* 683–692.

West, R. F., & Stanovich, K. E. (1986). Robust effects of syntactic structure on visual word processing. *Memory & Cognition, 14,* 104–112.

(Appendix A begins on next page)

Appendix A

Verb	Experiment	% completions: Noun phrase	Sentential	Other	*That* preference
		NP-bias verbs from sentence completion study			
Accept	1, 2, 3	93	0	7	—
Advise	1, 2, 3	93	7	0	100
Confirm	2, 3	100	0	0	—
Forget	1, 2, 3	57	0	43	—
Learn	2, 3	64	21	15	100
Maintain	2, 3	79	21	0	66
Observe	1	86	14	0	100
Recall	2, 3	100	0	0	—
Remember	1, 2, 3	57	0	43	—
Reveal	2, 3	79	21	0	100
Teach	1	100	0	0	—
Understand	1	86	14	0	100
Warn	1	50	21	29	100
Write	2, 3	57	0	43	—
		Sentence-bias verbs from sentence completion study			
Boast	1, 2, 3	0	43	57	100
Claim	2, 3	7	71	22	60
Decide[a]	1, 2, 3	7	7	86	0
Hint	1, 2, 3	0	71	29	100
Hope	1, 2, 3	0	64	36	29
Imply	1, 2, 3	21	79	0	91
Insist	1, 2, 3	0	71	29	70
Pretend	1, 2, 3	0	50	50	57
Realize	1, 2, 3	7	93	0	62
Wish	2, 3	0	86	14	17
		All other verbs from sentence completion study			
Admit		36	57	7	63
Agree		0	29	71	100
Argue		7	7	86	100
Assert		50	43	7	67
Believe		21	29	50	50
Brag		0	21	79	67
Confess		43	43	14	100
Deny		50	43	7	100
Dispute		93	0	7	—
Doubt		36	57	7	50
Dream		0	21	79	66
Feel		36	21	43	66
Figure		0	43	64	17
Guess		43	21	36	66
Infer		43	50	7	100
Mention		43	57	50	100
Notice		50	50	0	86
Pray		0	29	71	75
Predict		57	43	0	50
Promise		7	0	93	—
Protest		43	7	50	100
Remark		0	0	100	—
Speculate		21	21	58	100
Suppose		0	93	7	46
Suspect		29	71	0	60
Think		0	43	57	83

Note. *That* preference = percentage of sentence complement completions starting with *that.*
[a] Because of an initial scoring error, *decide* was accidentally included as a sentence-bias word.

Appendix B

Target Sentences From Experiments 2 and 3

1. a. The waiter insisted/confirmed (that) the reservation was made yesterday.
   b. The scientist insisted/confirmed (that) the hypothesis was being studied.
2. a. The chef claimed/remembered (that) the recipe would require using fresh basil.
   b. Mr. Smith claimed/remembered (that) the directions would need to be changed.
3. a. The general pretended/revealed (that) the weapon was ready to be used.
   b. The professor pretended/revealed (that) the answer was not correct.
4. a. The accountant hinted/advised (that) the client was cheating on his taxes.
   b. The attorney hinted/advised (that) the defendant was planning to jump bail.
5. a. The author boasted/wrote (that) the novel was likely to be a best-seller.
   b. The lawyer boasted/wrote (that) the memo was from the president of the company.
6. a. The defendant wished/accepted (that) the verdict would be decided soon.
   b. The man wished/accepted (that) the award would go to his brother.
7. a. The gardener decided/maintained (that) the lawn was in good shape.
   b. The mechanic decided/maintained (that) the engine was working reliably.
8. a. The student hoped/forgot (that) the solution was in the back of the book.
   b. The woman hoped/forgot (that) the address was in the directory.
9. a. The student realized/learned (that) the language was spoken only in one province.
   b. The apprentice realized/learned (that) the skill was quite marketable.
10. a. The teacher implied/recalled (that) the answer was very complicated.
    b. The poet implied/recalled (that) his childhood was very unhappy.

Note. The same verb never appeared twice in the same list.

Received May 1, 1992
Revision received August 24, 1992
Accepted October 5, 1992 ■