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Parsing temporarily ambiguous verb phrases

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City University of New York, 1990

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A

PARSING TEMPORARILY AMBIGUOUS VERB PHRASES

by

ANNIE LORING

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York.

1990

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Acknowledgements

Thanks, first of all, to Martin Chodorow, for his subtle and graceful guidance. Thanks also to Janet Fodor and David Swinney for valuable insights and clarifications all through the project, and to Virginia Valian and Caroline Carrithers for helpful suggestions closer to the end. Thanks of course to my parents, Simeon and Isobel Loring, for the basic tools. Special thanks to the members of my dissertation support group: Ann Zmitrovich, Leslie Tive, Marilyn Matevia, and Hiroshi Yamashita. To my friend Lisa Moisan and my niece and nephew Loulou and Georgios Tsangaris, thanks for your unconditional love. And most of all, thanks to Ray Miranda for making me so happy.

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CHAPTER ONE: INTRODUCTION

Parsing Temporarily Ambiguous Verb Phrases

Parsing is the assignment of structure to linguistic input. It is a process which occurs rapidly as people are understanding written or spoken sentences. When the incoming words are compatible with only one structure, or parse, then the process of assigning that single correct structure proceeds in a straight forward manner. However it is very often the case in everyday language, that at any given moment the words which have already been encountered can be assigned one of several possible structures. This structural ambiguity can be temporary, and resolved within the sentence as subsequent words are encountered, or it can be a global ambiguity, which is not resolved within the sentence at all.

- (1) The man saw the boy with a telescope.
- (2) The teacher met the boy.
- (3) The teacher knew the boy.
- (4) The teacher knew the boy had missed the exam.

Sentence (1) is globally ambiguous. It is not clear whether the man or the boy had the telescope. Disambiguating information is not available in the sentence but might be obtained from context. Sentence (2) is not structurally ambiguous. A noun phrase immediately following the verb "meet" can only be a direct object. Sentences (3) and (4) each have a temporary ambiguous region: the noun phrase "the boy." In (3), "the boy" is a direct object of the verb "knew." In (4), "the boy" is the subject of an embedded complement clause. Before the period ends the sentence in (3), or the word "had" is encountered in (4), the reader (or listener) does not yet know which

possible structure will be realized. How will the parser handle these temporary structural ambiguities that constantly occur? At which point in the analysis is the selection and commitment made? Is the decision reversible? And what kinds of information are used by the parser in making these choices?

When the parser makes a choice: Models of Analysis

Three models of parsing will be considered here: serial, parallel, and delay. Each can be experimentally distinguished by the location of increased processing load, operationalized in the literature as various reaction time measures (reading time, lexical or syntactic decision time), error rates, eye movement analyses, and the measurement of physiological changes associated with cognitive effort. Since processing load is measured in so many different ways, and specific measures may be more sensitive to some aspects of the process of sentence comprehension than to others, many of the disparities in results can be attributed to differences in method. Nevertheless, one would hope that general predictions about the location of heavier processing loads for each of the parsing models can be made regardless of how this load is measured.

In the serial model, a preferred structure for the ambiguous string is computed as the words are encountered. (The factors involved in the selection of a preferred structure will be discussed below.) Processing load increases when the sentence is disambiguated in the nonpreferred direction, forcing backtracking and reanalysis. In other words, if the preferred structural assignment also turns out to be the correct one, the parser will have been right

the first time and show no increased processing load. Only if the disambiguating word comes as a surprise to the parser, and a second structural assignment must be made, will there be evidence of an increased difficulty in processing. (This situation, of course, is the classic "garden path" of the parsing literature. In its selection of the incorrect analysis the parser was led down the garden path.) This processing difficulty should appear only at the disambiguating word when the parser is first alerted to its error, perhaps extending for an additional word as the second analysis is being computed, and only in sentences for which the correct structure is the one which is not preferred.

In the parallel model, the parsing mechanism is alert to possible ambiguities as they arise. This does not imply that the person is consciously aware of these ambiguities. In this model, all possible structural analyses are computed at the onset of the ambiguous region and maintained until the sentence is disambiguated, when only the correct analysis is carried on to the rest of the sentence. Assuming a resource limited system, a heavy processing load relative to a similarly structured but unambiguous sentence might begin at the onset of the ambiguous region and end at the disambiguating word, no matter which structure is finally seen to be correct. The parser could conceivably operate in this manner without being a resource limited system. Then increased processing difficulty would be very difficult to detect. A method which tests for availability of alternate interpretations during parsing rather than increased processing loads would be necessary. Work done by Gorrell (1987) in this area will be discussed below.

In the delay model, assignment of structure is postponed until enough information is present to assign the correct structure. Unlike the other models which allow the parser to entertain several hypotheses simultaneously or to make a decision but later change it if necessary, the delay parser is deterministic. The parser may do preliminary processing of individual words, but attempts to wait to attach the constituents into a sentence structure until it can be right the first time. This delay can be problematic as memory demands for incompletely structured materials are much greater than for highly structured materials (Miller, 1956). Because less structured material places a greater demand on memory resources than structured input, the increased processing load may be expected to begin at the onset of the ambiguity and increase as each new item is encountered during the ambiguous region. At the point of disambiguation, maximal load would occur, when all the processing work which had been postponed up to that point would have to be done. There is likely some limit to the number of partly structured items which can be maintained in short term memory in addition to the sentence structure. If the sentence is disambiguated early enough so that this limit is not reached, then the parser will successfully delay processing until disambiguation occurs, and then form the single correct parse. However, if the ambiguous region is so long that this memory limit for unstructured material is reached, then the parser may arbitrarily choose a default preferred analysis rather than fail completely. If the sentence is actually resolved with a different structure, an increased processing load at the disambiguating word would reveal evidence of backtracking and

reanalysis.

There is empirical evidence in the literature supporting each view of when parsing decisions are made. This evidence will be better appreciated, though, after a brief discussion of the kinds of information the parser uses in making structural decisions.

What are parsing decisions based on?

In the serial and temporary delay models of analysis, the parser chooses a preferred analysis as an initial or default path through the ambiguity. In the parallel model, although all structures are in some way activated, there may be some ranking of alternatives which facilitates parsing efficiency. There are several sources of information that the parser may be exploiting to make these choices or evaluate and produce these rankings.

Although not universally accepted, certainly the most widely acknowledged general principle that the parser seems to use in its selection process is the principle of minimal attachment. This strategy is to attach incoming material into the phrase-marker being constructed using the fewest nodes consistent with the well-formedness rules of the language. That is, the simplest structure (as measured by the number of nodes) will be preferred in the absence of disambiguating information.

In addition to general principles, the parser may have access to information about individual lexical preferences. The probability that a given verb will be followed by any particular structure can be determined by the frequency of occurrence of that structure after that verb. This information

may be present in the lexical entry for each verb in the lexicon and thus available to the parser. Although it has not been empirically demonstrated that structural preferences of individual verbs and frequency of occurrence of these structures are closely associated, the assumption that they are seems reasonable.

It is even possible that semantic or pragmatic information is used by the parser in the selection or ranking of structural alternatives. The kinds of information that the parser seems to have access to will be discussed in greater depth below.

Review of Research Methods

Understanding one's native language usually feels instantaneous and effortless. Parsing processes begin and are completed in a short period of time and are generally inaccessible to conscious awareness. Only extreme failures of the process are noticed. Because of this, subjects cannot be relied on to report how they went about understanding an ambiguous sentence. Even their final interpretation is of limited usefulness for solving the problem of how that interpretation was obtained.

There are two main classes of evidence that are used to infer parsing strategies. The first is measurements of processing difficulty. Since language understanding is not ordinarily a resource limited task, subjects are required to process the presented linguistic material while concurrently doing some additional task which is designed to limit the cognitive resources available to the language understanding task. When the concurrent task is sufficiently demanding, language processing efficiency drops to measurable

levels. Alternatively, measurements on the concurrent or secondary task may be easier to make. When the linguistic materials are more difficult to process, performance on the secondary task will suffer.

The second class of evidence used to make inferences about parsing strategy consists of the results of syntactic priming experiments. Secondary tasks are also used here, but with a different goal. The idea is that a subject will respond more quickly (on a secondary task) to a word stimulus that is consistent with the structure that is at that moment being constructed by the parser than to an inappropriate word. If there is more than one structural interpretation being constructed, then at least two categories of words will be responded to faster than a control word that is incompatible with any possible structural analysis. If only a single analysis is computed at a time, then response time to only one class of words will be faster. Stimulus words which are only syntactically appropriate for the nonpreferred structure are included in the materials. If the nonpreferred structure is not being computed at that moment, then response times for these stimulus words should be as slow as response times to the completely inappropriate control words. Shorter response times to words which are syntactically appropriate for only the nonpreferred structure are used as evidence that the nonpreferred structure is being computed. Results of this kind of study can reveal whether structures which are not present at the end of the comprehension process were being used by the parser at any point in the analysis.

Processing difficulty has been measured in many different ways. One measure which is notable for its lack of intrusiveness into the cognitive

process is the measurement of eye movements that occur during reading. Longer fixations on particular portions of sentences are taken to mean that more cognitive effort is required to process those regions than others in the sentence. Visual regressions to earlier points in the sentence may reveal where the critical information is obtained by the parser to revise misanalyses.

The other primary measures of processing load are chronometrics and error analyses. As processing becomes more difficult, performance can degrade along two dimensions: speed and accuracy. Typically, subjects are timed as they read through a sentence. Words or regions which take longer to understand should also take longer to read. Empirically though, simply reading through a sentence word by word on a computer has not always provided a sufficiently sensitive measure of processing difficulty. Timed keypresses will not accurately reflect processing loads if subjects pace rapidly through the keypresses and rely on either their memory of the sentence or an opportunity to reread material remaining on the screen. To make every keypress a meaningful measure, subjects often must make some kind of judgment about each word or region before being allowed to view the next one. These judgments are generally either lexical decisions (do those letters form a real word?) or syntactic decisions (can a grammatical sentence continue with the addition of that word?). Decisions like these can be made on every word or only some words in a sentence. Decision times are used as a dependent variable when accuracy rates are high. Even at accuracy rates of close to 100%, variations in the latency of correct decisions can be

very revealing. For error analyses to be meaningful, the task must be difficult enough that performance accuracy is less than perfect. Presenting materials at a uncomfortably fast rate is one way to obtain useful error measurements. This can be done with visual or auditory materials. Another indirect method of measuring processing load is phoneme monitoring. If asked to press a button whenever a specific letter sound is heard, the subject should take longer to detect the phoneme when processing a difficult structure than when processing a simpler one.

The secondary tasks used in the priming studies also rely on timing of lexical and syntactic decisions. In these studies though, decisions are generally made on items which are not part of the sentence being read. The sentence is interrupted at a point of interest with a probe item. The point of presentation and syntactic appropriateness of the probe item are manipulated. Responses to the probe items are timed and compared. The research methods which are currently in vogue share a focus on detection of changes that occur while syntactic parsing is ongoing. Although comprehension tasks which take place after a sentence has been understood do reveal the final outcomes of parsing different kinds of materials, the "on-line" measurements described above are more sensitive than post-sentential tests to the actual process of parsing.

The Serial Model

Much of the literature that sorts and describes factors which determine which structural analysis is the preferred one assumes the parser's use of a serial strategy to parse ambiguous material. Ford, Bresnan and Kaplan

(1981) discuss the interaction between the use of heuristic strategies and lexical information by the parser in determining which is the preferred reading of any string. Using globally ambiguous sentences, they demonstrated how early closure of a noun phrase is generally, but not always preferred. For example, in the sentence:

(5) Joe bought the book for Susan.

subjects preferred the interpretation that Joe bought something (a book) for Susan, rather than that what he bought was [a book for Susan]. The noun phrase tended to be closed early (after "book"), rather than late (after "Susan"). However, this preference for early closure was not invariable.

(6) The women discussed the dogs on the beach.

In sentence (6) above, subjects preferred the interpretation that the women were discussing the dogs that were on the beach, rather than that the women were discussing something (the dogs) while the women themselves were on the beach. Here, late closure of the noun phrase was preferred. The authors were able to manipulate structural preference simply by replacing "discussed" with the verb "kept."

(7) The women kept the dogs on the beach.

For this sentence, subjects preferred the interpretation that the women are keeping them (the dogs) on the beach, rather than that they are keeping those particular dogs (the ones on the beach). Changing just one lexical item, the verb, altered the preference to the structure not predicted by minimal attachment. The authors argue that the closure of a phrase is influenced not only by the application of general parsing rules but by lexical preferences as well. In globally ambiguous sentences, both interpretations are possible all

the way through the sentence. However in a locally ambiguous sentence, selection of a wrong structural assignment means that a reanalysis is required if the sentence is to be understood.

(8) The tourists signaled to the guide that they didn't like.

In sentence (8), the reader is probably surprised when the end of the sentence is abruptly encountered. The verb "signal" in its strongest form is followed by the word "to", an object, and then a complement clause. Here however, only the less preferred structure, simply following the verb with "to" and the object is appropriate. According to the authors, when the weaker (less frequent) form of an structurally ambiguous lexical item is required, reanalysis occurs. These reanalyses occur often and are only rarely experienced consciously by the reader.

Frazier and Rayner (1982) tracked eye movements of subjects as they read temporarily ambiguous sentences. They used materials in which a postverbal noun phrase could be a direct object of the preceding verb, or a subject of an embedded sentential complement to the verb (a complement clause). They also varied the length of the ambiguous noun phrase. A sample stimulus set follows.

(9) His second wife will claim the inheritance.

(10) His second wife will claim the entire family inheritance.

(11) His second wife will claim the inheritance belongs to her.

(12) His second wife will claim the entire family inheritance belongs to her.

Using average reading rate (ms per letter) as the dependent variable, they found that sentences which contained complement clauses were more difficult to process than sentences in which the ambiguous noun phrase was a

direct object of the verb (51 ms/letter to 49 ms per letter in the short noun phrases, and 61 ms/letter to 45 ms/letter in the long noun phrases), and that the long noun phrase complement sentence was more difficult than all other versions. This increase in overall processing difficulty in sentences which violate minimal attachment preferences supports the parser's use of a serial strategy. The authors' stronger findings, however, occur when the pattern of regressive eye movements was monitored. More regressive eye movements were made for versions (11) and (12), the complement clause endings, than for versions (9) and (10), the direct object endings. Subjects typically made a long (more than 300 ms) fixation on the disambiguating word, followed immediately by a regression to the ambiguous area of the sentence. These findings of increased fixation durations at the point of disambiguation and regressive eye movements to the ambiguous region when the sentence is resolved in the nonpreferred direction support the idea that subjects are reanalyzing the structure.

The Parallel Model

Gorrell (1987) found empirical support for computation of multiple analyses of ambiguous strings. Using a lexical decision task timed to occur before the disambiguating information was available, he recorded reaction times to syntactically preferred, syntactically nonpreferred and completely unrelated lexical items. His materials included both main verb/passive participle ambiguities and direct object/complement clause ambiguities. Each set of materials had an unambiguous simple sentence (corresponding to a minimal attachment resolution of the ambiguous string), an unambiguous

complex sentence (corresponding to the ambiguous version which resolves in violation of minimal attachment), and an ambiguous version. Subjects made a single lexical decision on a target item presented at the slash mark.

Main Verb/ Participle ambiguity:

- | | |
|-----------|--|
| SIMPLE | (13) The company was loaned money at low rates/ |
| AMBIGUOUS | (14) The company loaned money at low rates/ |
| COMPLEX | (15) The company they loaned money at low rates/ |

Direct Object/complement clause ambiguity

- | | |
|-----------|--|
| SIMPLE | (16) It's obvious that Holmes saved the son of the banker/ |
| AMBIGUOUS | (17) It's obvious that Holmes suspected the son of the banker/ |
| COMPLEX | (18) It's obvious that Holmes realized the son of the banker/ |

For the experimental sentences, the target items were high frequency verbs (e.g. "was") or pronouns. Pronouns were ungrammatical continuations of all versions. The verb target was a predicted continuation for the unambiguously complex sentence. It was also a predicted continuation for the non-minimal attachment reading of the ambiguous sentence. Gorrell found that for the ambiguous sentences, lexical decision times to these verbs (syntactically nonpreferred items) were faster than decision times to the pronouns (completely unrelated items). This implies that the nonpreferred structure is present prior to disambiguation, a finding that supports the use of a parallel parsing strategy. The parallel model is the only one that makes a nonpreferred syntactic structure available before the disambiguation of the string. The serial parser has only the preferred analysis ready, and the delay parser has either unstructured material or the default preferred reading prior to disambiguation. Both main verb/participle

and direct object/complement clause ambiguities showed evidence of syntactic priming of the nonpreferred structure.

Kurtzman (1985) suggests a ranked parallel model to explain his own data. Using a grammatical acceptability judgment task timed to occur at the point of disambiguation, he found that by manipulating the pragmatic plausibility of a particular structural analysis of a sentence, he could force the parser to prefer the syntactic structure which is ordinarily not preferred. The presence of the locative "there" in that sentence position may influence phrase closure, but if either structure could be preferred depending on biasing context or other factors, then both structures must have been present before disambiguation. A reversal of preference occurred in only one of his sentence sets. The syntactic decision targets were either "our" or "are". The sentences are followed by the percent correct responses for each target, and the decision time in ms.

(19) The diaries recorded there (a) our: 73%, 702 ms. (b) are: 53%, 586 ms.

(20) The scenes recorded there (a) our: 27%, 743 ms. (b) are: 80%, 639 ms.

The replacement of "diaries" with "scenes" before the verb "record" allowed the non-minimal attachment reading in sentence (20) to be responded to faster and with greater accuracy than when "record" was the main verb of the sentence. Thus this also supports the parallel model.

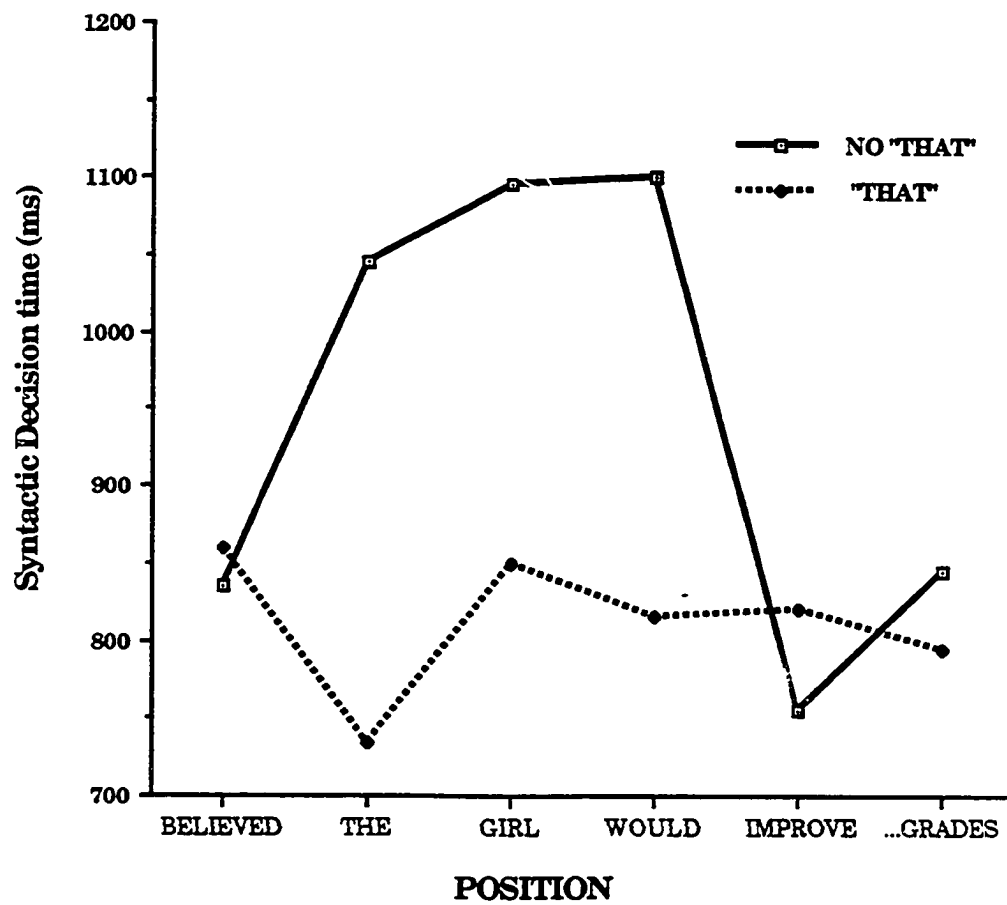
The Delay Model

Slutsky (1989) suggests that the parser uses the delay strategy. He used a continuous syntactic decision task, in which subjects made a grammaticality judgment on each item as they read word-by-word through a sentence.

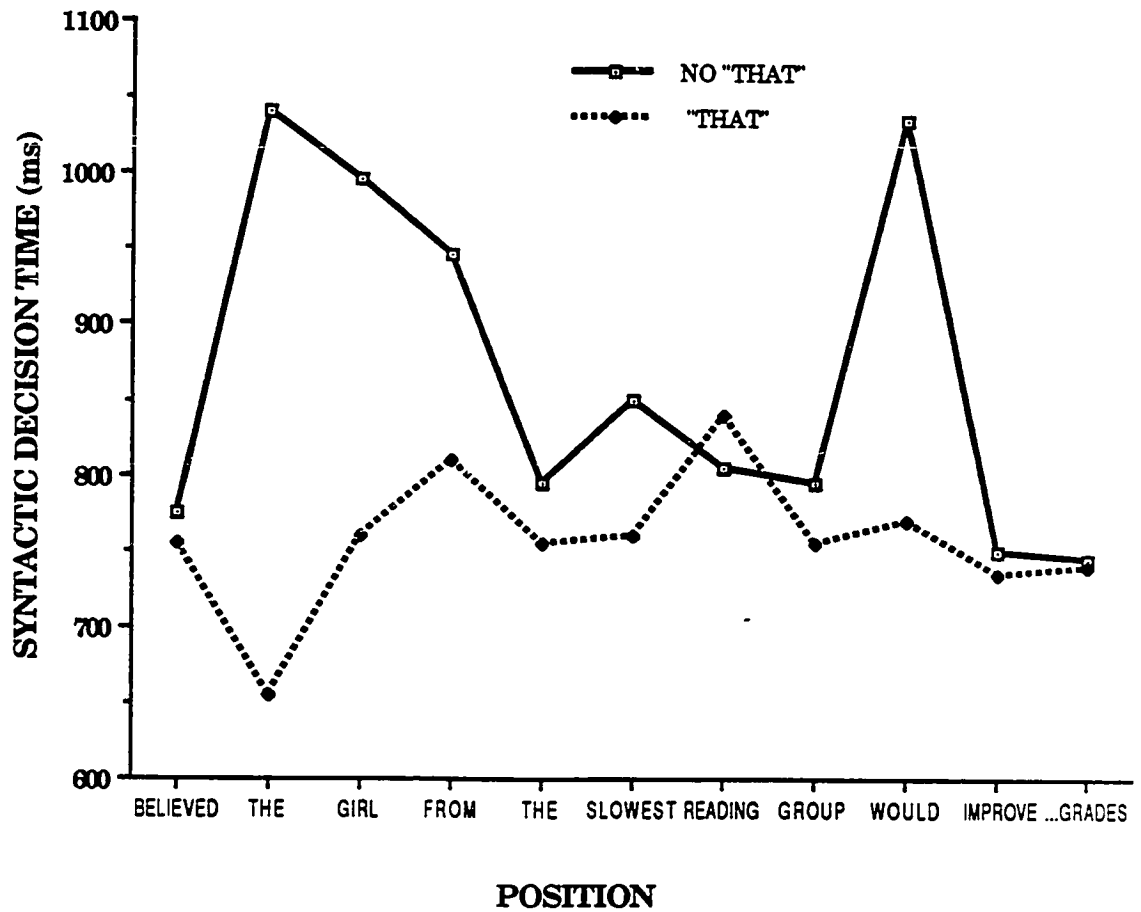
(21) The teacher believed the girl would improve her grades.

(22) The teacher believed the girl from the slowest reading group would improve her grades.

Using materials with short ambiguous regions in noun phrase/complement clause ambiguities (sentence 21), an increased processing load relative to unambiguous controls first occurred at the onset of the ambiguous region. (See figure 1). This increased load continued to grow until the disambiguating word was encountered. After that, it then decreased to normal levels by the end of the sentence. Over long ambiguous regions (sentence 22), two distinct peaks of processing load were seen (Figure 2). The first began at the onset of the ambiguous region and ended two or three words later. Another occurred at the point of disambiguation. Several words measured between those peaks showed only a normal load. A plausible explanation for this return to normal levels several words into the ambiguous region is that the parser has reached its memory limit for unstructured material (or, in the case of the parallel model, multiple structures), and makes a decision to default to the preferred structure, which causes backtracking when the sentence is disambiguated in the nonpreferred direction. This return to normal levels is part of what distinguishes the delay model (and only momentarily parallel ones) from a parallel processor without such resource limitations. However, an alternative explanation for an increased load at the disambiguating word which is consistent with a parallel processor does exist. Even though both structures are present prior to disambiguation, when the correct structure is finally selected, some reallocation of cognitive resources may occur which could in turn cause an

Figure 1: Slutsky (1989)

Slutsky (1989)



increase in processing load. The difference in delay and parallel predictions described earlier rests on two assumptions. The first is that dropping an incorrect analysis at the point of disambiguation does not cost the parser anything. If the reallocation of resources were costly, then the predictions of delay and parallel models look very much the same. The second assumption is that parallel parsing is costly in the ambiguous region. If there were no cost to parallel processing, then only the delay model would predict an increased load in the ambiguous region.

Complexity and Ambiguity: Separable Effects?

In studies of ambiguity processing there is a frequently confounding variable which must be controlled. This variable is complexity, or the number of possible argument structures which can follow a particular verb. A complex verb, one which can be followed by more than one kind of argument structure may be more difficult to process than a simple verb, one which is consistent with only one argument type. This effect of verb complexity may occur independently of ambiguity, even in structurally unambiguous contexts.

There has already been a great deal of work in the literature laying the foundation to sort out this confound. Fodor, Garrett and Bever (1968), using paraphrasing and anagram solving tasks, found that sentences containing complex verbs were more difficult to understand than sentences containing simple verbs. Hakes (1971) used an on-line phoneme monitoring task and a post-sentential paraphrasing task. In his materials, the complexity of the verb preceding a direct object noun phrase was varied, and the phoneme to be

detected was presented at the noun which was a direct object of either a simple or a complex verb. Hakes found no effect for complexity of the verb in the phoneme monitoring task, but did find an effect in the paraphrasing task. He postulated that verb complexity has its effect later on in processing, either after a clause boundary, or during comprehension processes which take place when the sentence is structurally disambiguated. These negative results provide indirect evidence for a serial (or delayed) parse, because the presence of two or more possible argument structures after a complex verb would have slowed down detection of the phoneme. Unfortunately, at the position monitored, the phoneme is embedded in a structurally ambiguous string only when following the complex verb. This means that the structurally complex sentence is also ambiguous while the simple sentence is also unambiguous, a perfect confounding of the two variables.

Hakes' finding that an increase in verb complexity did not affect speed on a secondary task was atypical. Both Holmes and Forster (1972), using rapid serial visual presentation of materials (RSVP), and Chodorow (1979), using time-compressed speech, found that verbs which allowed both direct objects and sentential complements as arguments were more difficult to process than verbs which allowed only a direct object. This was evident even though both verb types were inserted in sentences without sentential complements. Holmes and Forster (1972) and Chodorow (1979), unlike Hakes, used only post-sentential measures of processing difficulty. However, their findings have been supported by researchers using more modern "on-line" methods.

Shapiro, Zurif and Grimshaw (1987) found that increased complexity of the verb did make an on-line secondary task take longer. Instead of phoneme monitoring, Shapiro et al. used a cross-modal lexical decision task. Experimental sentences were presented aurally and the lexical decisions took place on visually presented probes, timed to occur at different locations in the immediate temporal vicinity of the verb. Complex verbs were found to be processed with more difficulty than simple verbs. The aspect of verb complexity which seemed to most affect processing difficulty was found to be the number of possible argument structures that the verb could accept. Transitive verbs are the least complex, allowing only one configuration: the noun phrase after the verb must be a direct object. Nonalternating datives, which allow both the noun phrase direct object structure and a noun phrase followed by a prepositional phrase are considered the next complex category. Verbs which allowed sentential complements in addition to the direct object structure equal the nonalternating datives in complexity because both can accept two different argument structures. Alternating datives were classified as the most complex, because they can accept three different structures: noun phrase direct object alone and noun phrase followed by a prepositional phrase like the nonalternating datives, plus a double noun phrase structure. Because lexical decisions on the probe item took longer when following a complex verb rather than a simple one, the data support the claim that all argument structures for a verb are momentarily active, an indicator of early parallel processing. Schluroff, Zimmermann, Freeman, Hofmeister, Lorscheid, and Weber (1986) used pupillary dilation as a

measure of psychological complexity to test for a correlation between psychological and grammatical complexity. They found that in globally ambiguous German sentences, structurally more complex sentences were also psychologically more complex. Also, structures which are much likelier to occur (high bias structures) tended to be processed more easily than low-bias structures, although the effect was not quite significant.

Do Lexical Biases Influence Parsing?

Although Shapiro et al. (1987) found that verb complexity was not determined by the syntactic category of possible arguments, structural biases or preferences for particular argument types do exist for specific verbs. These biases, sometimes called lexical expectations or verb frame preferences, may influence or even alter a general strategy used by the parser. Connine, Ferreira, Jones, Clifton and Frazier (1984) established some descriptive norms for many common verbs by measuring frequencies of different argument structures generated by subjects using stimulus verbs in a sentence writing task. Clifton, Frazier and Connine (1984) found that information about these preferred subcategorization frames is used very quickly during sentence processing. They used complex verbs classified as predominantly transitive or intransitive, and constructed materials so that each verb appeared in both contexts. A sample stimulus set follows. Although both verbs shown can be used in either transitive or intransitive contexts, the verb "read" is more commonly followed by a direct object than the verb "sing".

(23) The babysitter read the * story to the sick child.

(24) The babysitter sang the * story to the sick child.

(25) The babysitter read to * the sick child.

(26) The babysitter sang to * the sick child.

Subjects read the sentences word by word and were interrupted with a lexical decision task between the determiner and the noun of the direct object noun phrase in the transitive context, or after the preposition in the intransitive context. The interruption points are shown with asterisks. Decision times were significantly faster on the secondary task when the phrase following the verb matched its preferred argument frame than when it mismatched the frame. This suggests that the parser does not use a general strategy for selection of a preferred argument structure for all complex verbs. Instead, the parser seems to have access to structural preferences of individual verbs during its analysis. Not only are complex verbs apparently processed differently from simple ones, but among complex verbs themselves, there are structural preferences which seem to influence parsing strategy.

The issue of lexical preferences was also addressed by Mitchell and Holmes (1985). They compared preferred and nonpreferred resolutions of local structural ambiguity. Although complexity and ambiguity were confounded by the absence of unambiguous control sentences in the same experiment, they did find increased reading time in the disambiguating "indicator segments" of several types of ambiguous sentences which for specific verbs were resolved in the nonpreferred direction. For example, six experimental sentences out of the 24 measured direct object/clausal complement ambiguity. The verbs were divided on the basis of preference for direct objects or complement clauses, paired with a verb with the opposite

preference, and placed in identical sentence frames to be compared. All ambiguities were resolved with a complement clause ending. A sample experimental set follows. The first verb in this set was classified as a complement biased verb because 84% of subjects had used that ending type in an earlier sentence completion task. The second verb was classified as a direct object biased verb because only 48% of subjects had completed the sentence with the clausal ending. Different subjects were used for the sentence completion and reading time experiments.

(27) The doctor feared the letter he wanted to send had been lost.

(28) The doctor dreaded the letter he wanted to send had been lost.

In four out of the six sentence pairs, reading times were longer in the underlined indicator segments for the direct object biased verbs which ended with the complement clause (sentence 28). In only two of the six, reading time of the indicator phrase was longer for sentences containing both the clausal biased verb and clausal ending. The results suggest specific lexical influences on parsing, although too few examples of this form of ambiguity were tested to measure statistical significance. The results would also have been easier to interpret if both direct object and clausal resolutions had been explicitly tested for each verb.

To complicate matters, Holmes, Kennedy and Murray (1987) reported data which showed that complexity of the verb had an effect on processing difficulty, but that ambiguity did not. They constructed sentence sets like the following.

(29) The maid disclosed the safe's location within the house to the officer.

(30) The maid disclosed the safe's location within the house had been

changed.

(31) The maid disclosed that the safe's location within the house had been changed.

Sentence (29) contains a long structurally ambiguous noun phrase which resolves as a direct object. Sentence (30) is identical to sentence (29) up to the point of disambiguation, when the noun phrase is resolved as a complement. Sentence (31) unambiguously prepares the reader for a complement clause with the presence of the complementizer "that." A cumulative, word-by-word reading task was used and the materials were later segmented into phrases for analysis. Subjects spent more time reading the words in a clausal complement phrase than in a direct object phrase, even when the clause was unambiguously introduced with the complementizer. Surprisingly, no difference in reading time was found between the two complement versions, with and without the complementizer. Although the words in the two kinds of phrases were roughly matched for length and frequency, the experiment lacks a corresponding unambiguous control sentence for the direct object resolution with exactly the same words in the critical region. These sentences could be constructed by having the noun phrases follow simple rather than complex verbs. Then the effects of complexity and ambiguity would be separable.

Rayner and Frazier (1987) measured eye movements of subjects reading the same materials used by Holmes, Kennedy and Murray in the study reported just above. Rayner and Frazier's intent was to evaluate the robustness of their previous findings using the materials which had just yielded such a surprising pattern. Their previous data had shown evidence of

increased processing loads at disambiguation of ambiguous strings relative to phrases of equal complexity which were unambiguously introduced. In the new experiment, complex verbs were used with clausal complements - either with or without the complementizer "that" present, with direct object endings, or with infinitival versions of the clause. Reading time was found to be significantly greater for the reduced (no "that") complement version in the disambiguating region than for the identical words in the unambiguous complement version, a confirmation of their original results. Differences in method were held responsible for the unusual findings of Holmes et al.

In another study of the effect of lexical preferences on the parser, Holmes, Stowe and Cupples (in press) sorted verbs by structural bias and tested them separately with complement clause endings with and without complementizers. Analyzing the two verb bias classes separately, they found a typical indicator of serial processing: a significantly increased processing load at the disambiguating word relative to the same word in unambiguously introduced complements. However, this result occurred only in sentences containing direct object-biased verbs. In sentences using clausal biased verbs, the reading time was also higher for reduced clauses at the disambiguating word than for the clauses introduced with the complementizer, but not significantly so. The authors did not test the statistical significance of this apparent interaction among verb bias, ambiguity and word position. Their work will be discussed further in the context of my Experiment 4 presented in chapter two.

Is the parser modular?

There is an ongoing discussion in the literature about how much and what kind of information is available to the parser in constructing syntactic analyses. Those who argue against the parser as an isolated module maintain that context and semantic considerations influence parsing decisions (Marslen-Wilson, 1985; Kurtzman, 1985). Proponents of modularity argue that the syntactic processor computes a structural representation for a given input string using only the output of the lexical processor and its own information base. Swinney (1982) demonstrated that retrieval of word meanings during lexical processing involves accessing multiple meanings for ambiguous words, including a meaning which is not contextually appropriate. This finding rules out any influence of semantic context in the process of lexical access. If a similar separation between semantic and syntactic processing exists, then the parser should be resistant to manipulations of semantic context. Ferreira and Clifton (1986) used eye movement measures to determine whether syntactic biases that have been observed in sentences presented in isolation could be overcome by contextual influences. They used sentences which contained relative clauses, either unambiguously introduced or "reduced". In ambiguous sentences, the relative clause structure violates minimal attachment preferences and would be expected to cause processing difficulty at the disambiguating word. The nouns used as sentence subjects were either animate or inanimate, and therefore plausible or implausible in their materials in the active minimal attachment reading. A sample sentence set follows.

(32) The defendant examined by the lawyer turned out to be unreliable.

(33) The evidence examined by the lawyer turned out to be unreliable.

(34) The defendant that was examined by the lawyer turned out to be unreliable.

(35) The evidence that was examined by the lawyer turned out to be unreliable.

Sentences (32) and (33) are ambiguous at the first verb (examined). In sentence (33), the ambiguous inanimate version, "the evidence examined" is implausible in the minimal attachment reading. If contextual plausibility was a cue that was available to the parser, then sentence (33) should have been assigned the relative clause analysis immediately and thus not show evidence of reanalysis later (at the disambiguating by-phrase). It was found that the syntactic processing biases remained even when they conflicted with discourse bias. These results were replicated using a self paced reading task.

Trueswell, Tanenhaus and Garnsey (1989) monitored eye movements of subjects who were reading similar materials containing main verb/passive participle ambiguities. All the ambiguities were resolved as participles. These were presented in both reduced and unreduced conditions. Subjects of the sentences were either animate or inanimate. An additional group of control sentences contained verbs whose passive participle form was not the same as the past tense form (for example, drive: driven/drove). Although Ferreira and Clifton (1986) had found no effect for animacy on the parsing of these kinds of materials, Trueswell et al. purposely confounded animacy with plausibility of the nouns as reasonable Agents of the verb. This confound had occurred by chance in much of Ferreira and Clifton's

materials, but Trueswell et al. were testing not just the effects of an inanimate noun on the preference for the minimal attachment reading, but the effects of an inanimate AND implausible subject on this preference. They obtained an increase in reading time in the reduced condition compared to the unambiguous condition only for animate subjects (which were also plausible Agents). For inanimate nouns (which were also implausible Agents), there was no difference between the ambiguous and unambiguous conditions. Therefore, the implausibility of the noun as the subject of a main verb construction seemed to cause the ambiguous string to become a functionally unambiguous participle. This evidence seems to indicate that the parser is utilizing contextual information, a finding which does not support the modularity thesis.

The effects of verb bias and plausibility were explored further by Holmes, Stowe and Cupples (in press). They manipulated pragmatic plausibility of objects of complex verbs used in direct object/complement clause ambiguities. The verbs were classified into syntactic bias categories. An example set follows.

- (36) The reporter saw her friend was not succeeding.
- (37) The reporter saw that her friend was not succeeding.
- (38) The reporter saw her method was not succeeding.
- (39) The reporter saw that her method was not succeeding.

The nouns were plausible or implausible as direct objects. All sentences were disambiguated as complement clauses. Unambiguous complement clause sentences used the complementizer "that". Although the authors did not test the statistical significance of the apparent interaction

obtained, they report that object plausibility had different effects in the two biasing conditions. There was no difference in reading time between sentences containing plausible and implausible direct objects after complement-biased verbs (e.g. say, claim, discover, know, forget), but object plausibility did have an effect after direct object-biased verbs (e.g. see, judge, recognize, hear, remember). However, plausibility did not affect time spent reading the disambiguating region as would be expected if readers were having difficulty understanding the sentence. Instead, the implausible noun itself was read for more time, in both ambiguous and syntactically unambiguous conditions. The reasons for this are not clear, and therefore these results are not necessarily incompatible with a modular parser.

The Present Study

One object of the research which will be described here is to determine which kinds of constraining information are available to the syntactic parsing routines and which are not. Another is to see which theoretical parsing model best accounts for this new data. Continuous syntactic and lexical decision tasks will be used to track increases and decreases in processing load as they occur. The materials are designed in such a way that each ambiguous experimental sentence can be compared to an unambiguous control sentence that matches it closely in all ways except the one being explicitly manipulated. In most cases, the identical words are used. Ambiguous sentences are tested using both possible resolutions, each with its corresponding control sentence. When the effects of animacy are manipulated, animate and inanimate subjects are carefully chosen to be

plausible in both structural contexts. Plausibility effects are tested separately, without confounding these effects with the effects of animacy. Length of the ambiguous regions is also manipulated. Effects of verb bias will be tested for statistical significance.

(40) The patient shaved in bed but got up to brush his teeth.

(41) The patient shaved in bed was very grateful.

(42) The detective revealed the burglars when he pulled back the curtain.

(43) The detective revealed the burglars were now out of the country.

The experiments will monitor the parser's performance on two types of temporary structural ambiguity: main verb/relative clause as in sentences (40) and (41), and direct object/complement clause ambiguity as in sentences (42) and (43).

CHAPTER TWO: THE EXPERIMENTS

Experiment 1

Syntactic Decisions on Main Verb/Participle Ambiguities

The methods used in the present experiments were derived from Ford (1983). The continuous syntactic decision and continuous lexical decision tasks measure changes in processing load as each new word is encountered during sentence processing. Subjects make a decision on each word before they can receive and read the next one in the sentence. The time it takes to make these decisions reflects parsing complexity. In Ford's experiments, words which had already been responded to remained on the screen, available for rereading. In the following experiments, each word is erased before the next one is presented. This change is intended to increase the difficulty of the task and force subjects to process the sentence as they are receiving the words, rather than allow them to rely on the opportunity to look back over previously presented material.

The first experiment was designed to test the sensitivity and reliability of the continuous syntactic and lexical decision tasks. Stimulus materials were selected for which there is some agreement in the literature about the parsing strategy people use. The sentences were typical of materials used to demonstrate the "garden-path" phenomenon. As described in chapter one, garden-path sentences cause a wrong analysis that the parser cannot easily

recover from. The sentences used here contained main verb/passive participle ambiguities which have been generally considered to be serially parsed (Bever, 1970; Fodor, Bever and Garret, 1974; Frazier and Rayner, 1982). That is, that there is an incorrect decision made at a certain point in the processing of the sentence. Processing difficulty at the disambiguating word in these kinds of materials is not subtle, so if the continuous syntactic and continuous lexical decision tasks are sensitive to changes in processing load during parsing, these changes should be clearly evident. In order to have a complete design, the ambiguous sentences are resolved in both directions. Each resolution has an unambiguous control sentence which matches it extremely closely at every corresponding position. In addition to the manipulation of ambiguity, the effect of pragmatically biasing context is examined to test for modularity of the parser. If the parser operates without semantic input, then differences in biasing context should not affect parsing strategy or difficulty.

Method

Subjects

Thirty two Hunter College undergraduates, all native speakers of English, served as subjects in the first experiment. Participation in the experiment was one of several options for "extra credit" points added to their grades in the undergraduate course Statistical Methods in Psychology. Non-native speakers were also run, in compliance with college policy on use

of students as experimental subjects, but their data were not considered in the following analyses. All data from subjects with errors in more than three of the sixteen experimental sentences were discarded and replaced. Nine other subjects were omitted from the final data analysis because of errors on all three examples of a given type of sentence. Two sentences were omitted from the final analysis because every subject exposed to one or more versions of those sentences made an error. Since stimulus sentences were terminated at the point where a subject decided the fragment was no longer grammatical, sentences with errors from every subject were omitted because mean decision times could not be obtained for word positions after the error.

Materials

As stated above, materials were of the type typically used in experiments measuring garden path phenomena. A sample set is shown below. The first verb in an ambiguous sentence could be parsed as either a main verb in the past tense or a passive participle of a "reduced" relative clause: a relative clause lacking a relative pronoun subject and a form of the verb be. Since subjects tend to read these kinds of ambiguities as main verbs, a pragmatic bias toward the participle reading was also included for each set to see if such a bias could affect the parser's strategy. In the example set below there is a bias toward the participle reading in the sentences with "the condemned prisoners" as the subject. The assumption is that condemned prisoners are more likely than musicians to be marched by someone else. The underlined

portions of the sentences are structurally ambiguous. The disambiguating words are immediately preceded by a pound sign (#). Words in bold type, preceding the potentially ambiguous words, make the control sentences unambiguous.

The musicians marched along the road #but collapsed on the swampy field
The musicians **had** marched along the road but collapsed on the swampy field
The musicians marched along the road #made the sheriff very nervous
The musicians **they** marched along the road made the sheriff very nervous

The condemned prisoners marched along the road #but collapsed on the swampy field
The condemned prisoners **had** marched along the road but collapsed on the swampy field
The condemned prisoners marched along the road #made the sheriff very nervous
The condemned prisoners **they** marched along the road made the sheriff very nervous

Periods were purposely deleted at the ends of sentences to avoid cuing the subjects with this information. Sixteen sets like this one were constructed, modifying materials previously used by Gorrell (1987). Subjects received only one sentence from each set. The experimental sentences were intermixed with sixty filler items with a variety of lengths and structures, about half of which were ungrammatical at some position in the fragment.

Procedure

Subjects were tested individually on a continuous syntactic decision task. They sat at a computer console and silently read instructions displayed on the screen as the experimenter read them aloud. The instructions were as follows:

This is called a syntactic decision task. You will be showing sentences to yourself one word at a time. Before you can see the next word, you judge whether the sentence is grammatical up to that point. If the sentence is still grammatically acceptable you will press the "+" key on the keypad on the right side of the keyboard. If the sentence is no longer grammatically acceptable you will press the "0" key on the keypad. Pressing "+" will allow you to see the next word in the sentence. Pressing "0" terminates the sentence. The sentence may become unacceptable at any time.

Before each sentence, a ready signal made up of asterisks will be on the screen. When you are ready to begin each new sentence, press "+" to see the first word. Thereafter, "+" means that the word is acceptable in the sentence.

The first ten sentences or parts of sentences will be practice items. The experimenter will stay with you during these items to answer any procedural questions, and then the regular items will begin. You will receive about a hundred sentences, with a short break in the middle. Make your choices as quickly as possible while trying not to make errors.

You will have another opportunity to ask questions after the practice sentences.

When ready to continue, the subject pressed the enter key and practice trials followed. Only a single word was visible in the middle of the screen, centered in a rectangular box to facilitate fixation. The word remained on the screen until the subject pressed either the "plus" key indicating that a

grammatically acceptable sentence could continue, or the "zero" key, indicating that the sentence could not be grammatically continued with that word. When the subject pressed the "plus" key, the word was erased and overwritten by the following word, which was also centrally displayed both in the box and on the screen. Thus the technique used a noncumulative and centrally displayed presentation of single words, none of which was followed by a period. When the entire sequence of words had been shown, the box disappeared briefly and was replaced with another one containing the "ready" signal. If during a trial a subject pressed the "zero" key to indicate that a sequence was no longer grammatical, the screen was cleared and a new trial was begun.

During the practice trials, the experimenter stood beside the subject giving verbal reinforcement for correct decisions (e.g. "that's right", "good"), and guidance about incorrect ones. After the ten practice sentences, the subject was left alone to complete the assignment at his or her own pace. The entire experiment took subjects about 20 to 40 minutes. All keypresses were timed to the nearest millisecond. Presses of the "ungrammatical" key in the experimental sentences were coded as errors. In the filler materials, a check of the position of "ungrammatical" responses was used to verify that the subject was making appropriate grammaticality judgments. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard

deviations above the mean for that subject.

Predictions of each model for these materials

If the parser follows rules of minimal attachment and operates serially, then the ambiguous sentences will initially be assigned a main verb structure. If the ending of the sentence is found to conform to this prediction at the point of disambiguation, no special increased loads would be seen anywhere in the sentence. There should be an increased decision time, and increased number of errors (judgments that the sentence is ungrammatical) at the disambiguating word only in sentences disambiguated with the participle ending.

Assuming processing with cost, the parallel model predicts a heavier processing load throughout the ambiguous regions regardless of the ending finally encountered, and no particular increase at the disambiguating word. The delay model (with cost) predicts an increasing load across the ambiguous regions due to memory constraints. This heavy load would continue to the disambiguating word and perhaps also to the following word as the delayed processing work is being done. If pragmatically biasing context affects parsing, then bias will interact statistically with the other variables. If there are no significant main effects or interactions with bias, then parser modularity will be supported.

Results and Discussion

The results show unequivocally that the materials were serially parsed.

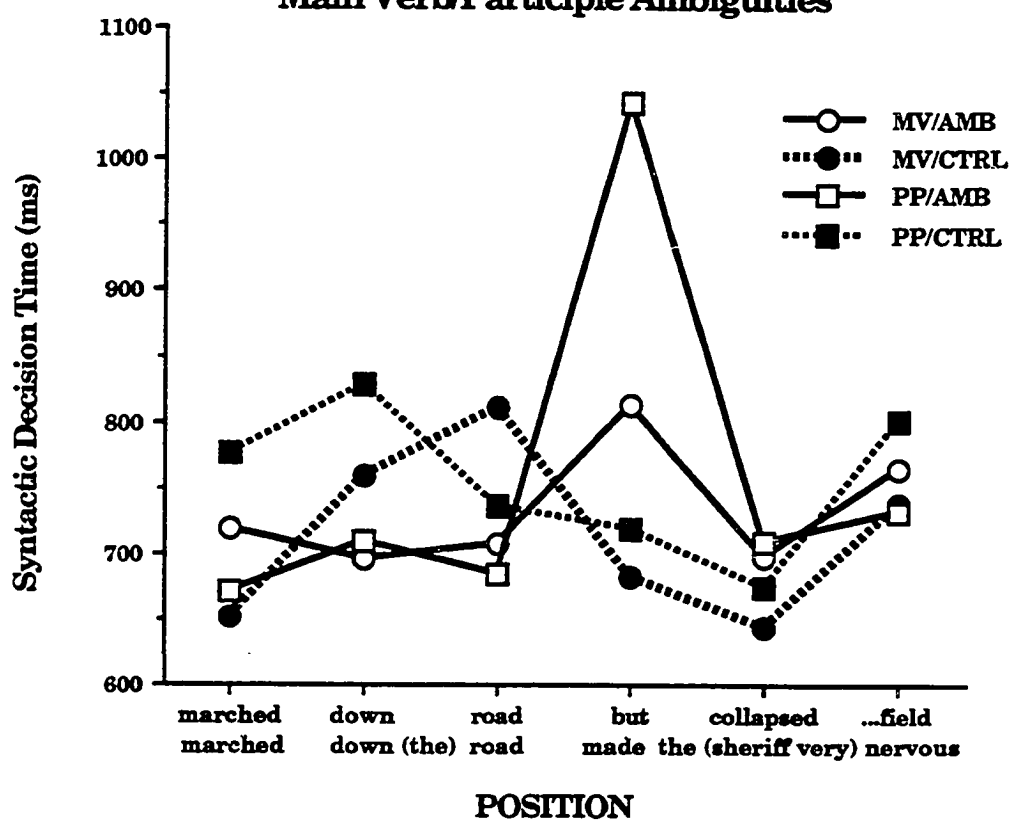
Subjects found the task moderately difficult. The grand mean decision time for all items was 736 ms. Two five-way Analyses of Variance were used with subjects and materials serving as random effects (Clark, 1973) in a repeated measures design. In each analysis, the random effect was crossed with resolution (main verb or passive participle endings), ambiguity status (ambiguous and unambiguous), pragmatic bias (toward main verb or towards participle reading), and word position (1 through 6). The specific word positions which were monitored were the verb (1), the first word of the ambiguous region (2), the last word of the ambiguous region (3), the disambiguating word (4), the word just after the disambiguating word (5), and the last word of the sentence (6).

Word position was significant as a main effect, $F_1(5,110) = 7.87, p < .0001$, and $F_2(5,65) = 3.78, p < .005$. This extremely robust effect that different words have on decision time is useful as a check that subjects are actually reading the sentences, rather than pacing mechanically through them. The interaction of sentence resolution by word position was significant in the subjects analysis and approached significance in the materials analysis: $F_1(5,110) = 4.30, p < .002$, and $F_2(5,65) = 2.25, p = .06$. This interaction shows that, without regard to ambiguity status, processing loads across the sentence follow slightly different patterns for the two types of endings. The interaction of ambiguity status by word position was highly significant: $F_1(5,110) = 8.46$,

$p < .0001$, and $F_2(5,65) = 14.95$, $p < .0001$. This interaction shows that regardless of which resolution is finally encountered, processing loads for ambiguous and unambiguous sentences follow very different patterns across the sentence. The most informative interaction for analysis of the parsing strategy for these materials is the three-way interaction of resolution (sentence ending) by ambiguity status by word position. This interaction tests whether the way ambiguity affects decision times for each word position is different depending on how the sentence is resolved. In particular, will a main verb resolution of an ambiguous phrase cause less difficulty at the disambiguating word (or anywhere else) relative to its unambiguous control than a participle resolution of the same ambiguous phrase relative to its own unambiguous control? This interaction was also significant: $F_1(5,110) = 4.65$, $p < .001$, and $F_2(5,65) = 2.56$, $p < .05$.

The means from this 3-way interaction are presented graphically in figure 3. Significant differences using the Duncan Multiple Range test occur only at position four: the disambiguating word. Sentences containing the temporary ambiguity which were resolved as participles show significantly longer decision times at the disambiguating word than their unambiguous participle controls at that position ($p < .01$). Ambiguously introduced participle endings require more processing time at the disambiguating word than ambiguously introduced main verb endings at the disambiguating word

Figure 3: Experiment 1
Main Verb/Participle Ambiguities



($p < .05$). The difference between sentences with ambiguously introduced main verb endings and their control versions is not significant at position four or anywhere else. This pattern at the disambiguating word clearly supports the serial model prediction. Since the ambiguous sentence with the main verb resolution is not significantly different from its unambiguous control at the disambiguating word, we can infer that the word is consistent with the structure being computed. The pattern at the disambiguating word is just the opposite for the ambiguous sentences which were resolved as participles. Here, the significantly longer time after the ambiguous region implies that the parser is surprised to encounter that word. The second verb is not consistent with the structure being computed and a structural reanalysis is required.

Within the ambiguous region, processing times for ambiguous versions are not consistently longer than for their unambiguous control versions, indicating that there is no extra processing cost associated with the presence of the temporary ambiguity in these materials. The presence of an increased load during the ambiguity would be evidence of some kind of parallel processing. Neither is there any gradual increase in processing load across the ambiguous region that would indicate a processing delay. (Although according to Frazier and Rayner, 1982, a delay in processing may not cause any increase in processing load simply because no processing is going on. Their prediction is that increased processing load would occur at

the disambiguating word in both versions of the sentence, when processing finally does occur.) The value of the continuous syntactic decision technique is evident here since information about processing loads at several sentence positions is readily available.

Error rates also support the serial model for these materials. Table 1 shows the frequencies of "ungrammatical" judgments classified by sentence type and word position. The errors are not equally distributed for each sentence type across the positions: $\chi^2(12) = 112.53, p < .001$. There are two cells in particular which have unusually high error rates. The first occurs before the verb in the unambiguous participle control sentence. This reflects subjects' objection to the word "they" in the construction:

The musicians #they marched down the road made the sheriff very nervous

This anomaly was unexpected and unfortunate because 50% of the subjects terminated these sentence types with the "ungrammatical" response before even reaching the ambiguous phrase. The second cell with a high frequency of errors occurs at the disambiguating word (or just after) in the sentence whose ambiguous region resolves as a participle. The errors (judgments that the sentence is no longer grammatically acceptable) occur when the main verb is encountered. It is at this point that the first verb is revealed to have been a passive participle. Errors which occur here indicate

Table 1

Number of "Ungrammatical" judgments from experiment 1 by position

	Position				
	BEFORE VERB	VERB	AMB. REGION	DISAMBIG.	TO END
MV-AMB	0	0	2	9	3
MV-CTRL	0	1	9	1	0
PART-AMB	0	0	2	20	1
PART-CTRL	32	2	6	1	0

that some subjects could not recover from the garden path.

Biasing context was not significant as a main effect or in any interaction, supporting the separation of semantic and syntactic processing.

The results of this experiment strengthen the position that the continuous syntactic decision task is indeed a sensitive measure of on-line parsing strategy.

Experiment 1a

Lexical Decisions on Main Verb/Participle Ambiguities

The lexical decision task was chosen because syntactic decision times are sometimes criticized as being too long to measure truly on-line processes. Syntactic decision times average around 700 ms and can be higher than one second per word. These latencies are much longer than the amount of time it takes to simply read and understand words in sentences. It is possible that these decision times long because the subject is showing the effects of performing several concurrent and possibly difficult tasks. Alternatively, conscious decision making may be going on that does not normally occur in natural sentence parsing. The lexical decision task was expected to yield shorter decision times, more typical of word by word reading tasks, yet retain a sensitivity to syntactic parsing that the syntactic decision task has already demonstrated. Since subjects are not consciously judging grammaticality,

the lexical decision task would appear to be better designed to measure changes in processing load during unconscious parsing as it more naturally occurs. If the patterns obtained in the previous experiment are replicated, then it is not likely that the long decision times are indicative of effects of conscious processing taking place after parsing has already occurred. The prediction is that the mean decision time will be shorter in the lexical decision task, but the general pattern of findings will be replicated. If this does not occur, the merit of the continuous syntactic decision task as well as the continuous lexical decision task as on-line measures of sentence processing will have to be questioned.

Method

Subjects

Thirty two Hunter College undergraduates participated and were remunerated with extra credit points. None had been subjects in the first experiment. All data from subjects with errors in more than two of the sixteen experimental sentences were discarded and replaced. Error rates overall for the lexical decision task were lower than for the previous experiment, and all 32 subjects and 16 sentences were included in the statistical analysis of the data.

Materials

Experimental materials from the previous experiment were reused with only one alteration. Because so many subjects made errors at the word "they"

in the relative clause sentences which were intended to be unambiguous control versions, these sentences were modified. The original:

The musicians ~~they~~ marched along the road made the sheriff very nervous

was modified to give the following clearer version:

The musicians ~~that they~~ marched along the road made the sheriff very nervous

All sets were modified in this way. In all other respects, experimental materials were identical to those used in the previous experiment. Filler items were changed such that items which had ended ungrammatically in the previous experiment now ended with nonwords.

Procedure

Presentation of the stimuli was identical to presentation in the previous experiment, i.e. a central, noncumulative display was still used. However, instead of a grammaticality judgment on each word, subjects made a lexical decision on each word. The instructions to the subjects were as follows:

This is called a lexical decision task. You will be showing sentences to yourself one word at a time. Before you can see the next word, you judge whether the letters on the screen form a real word in English. If the letters spell out a real word, you will press the "+" key on the keypad on the right side of the

keyboard. If the letters do not spell out a real word, you will press the "0" key on the keypad. Pressing "+" will allow you to see the next word in the sentence. Pressing "0" terminates the sentence. A non-word may appear at any time.

Before each sentence, a ready signal made up of asterisks will be on the screen. When you are ready to begin each new sentence, press "+" to see the first word. Thereafter, "+" means that the letters spell out a real English word. The first ten sentences or parts of sentences will be practice items. The experimenter will stay with you during these items to answer any procedural questions, and then the regular items will begin. You will receive about a hundred sentences, with a short break in the middle. Make your choices as quickly as possible while trying not to make errors.

You will have another opportunity to ask questions after the practice sentences.

Responses were timed and marked in the same way as for the previous experiment.

Results and Discussion

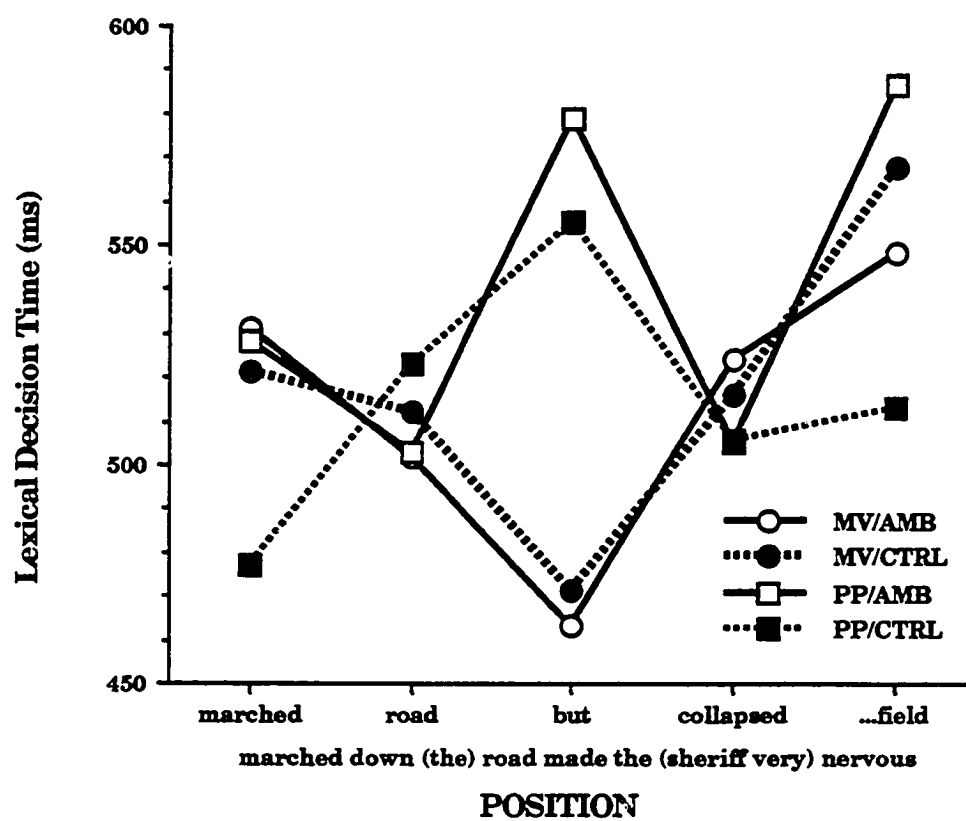
The overall pattern of results of the lexical decision task on these materials are not inconsistent with the use of a serial parse. The grand mean lexical decision time for the entire data set was 521 ms, shorter than the mean syntactic decision time (736 ms) for the same materials. The same kinds of analyses as were described above for experiment 1 were done. Once again, word position was highly significant: $F_1(5,155) = 10.53$, $p < .0001$, and $F_2(5,75) = 5.79$, $p < .0001$, indicating that subjects were actually reading the sentences and not simply pressing the response keys mechanically. Position also interacted significantly with sentence ending: $F_1(5,155) = 16.44$, $p <$

.0001, and $F_2(5,75) = 9.64, p < .0001$. This shows that regardless of whether the sentence is ambiguous or not, the two kinds of endings have different processing patterns across the sentence. Ambiguity status and word position significantly interacted: $F_1(5,155) = 5.84, p = .0001$, and $F_2(5,75) = 3.31, p < .01$, showing that ambiguous sentences are processed differently from unambiguous ones, no matter what the sentence ending. The interaction of particular interest, again, was the three-way interaction of resolution (sentence ending) by ambiguity status by word position. This was significant also: $F_1(5,155) = 7.28, p < .0001$, and $F_2(5,75) = 2.56, p < .05$. The means obtained from this interaction are shown in figure 4. Five sentence positions are represented: the first verb (which serves as either the main verb or the participle) is shown in position 1, the ambiguous region (position 2) is computed from an average of response times in the ambiguous region. Position 3 is the disambiguating word, a different word in the two sentence endings. Position 4 is the word following the disambiguating word in the sentence, and position 5 is the last word of the sentence.

Post-hoc Duncan Multiple Range tests show no significant differences between ambiguous and unambiguous versions with either sentence resolution at the disambiguating word. Example sentences are repeated below for reference.

The condemned prisoners/musicians (had) marched along the road but
collapsed on the swampy field

Figure 4: Experiment 1a



The condemned prisoners/musicians (who were) marched along the road
made the sheriff very nervous

The lexical decision task appears to be less sensitive than the syntactic decision task to subtle changes in processing load due to parsing. The overall pattern of the means indicates that the ambiguously introduced participle ending takes a little (24 ms) longer to process at the disambiguating word than the same word when the participle ending is unambiguously introduced, but this difference is not larger than one which occurs as early as the noun. There is essentially no difference (8 ms) between decision times at position 3 (the disambiguating word) for the ambiguous and unambiguous minimal attachment endings. The direction of these results can be used to infer serial processing, but not with any confidence. There is a striking difference, however, between the two sentence endings at the disambiguating word (position 3). The increased processing time for even the participle control sentence at position 3 relative to the main verb sentences can be explained by lexical effects. The subjects are responding to different words at this position for the two types of endings, and it is quite possible that the lexical decision task is more sensitive to effects of word length and frequency than the syntactic decision task. The other striking feature of figure 4 is the tremendous disparity in decision times at the last word in the sentence. The last word of the ambiguous participle version, disambiguated several words earlier, has a much longer decision time than the same word in the unambiguous participle resolution. It appears that the lexical decision task is

very sensitive to lexical differences, but less sensitive to syntactic ones. It is possible that the effects of parsing are demonstrated a few words after parsing has already occurred. Or perhaps the task itself encourages a delay in syntactic processing, so that parsing actually takes place several words later than in the syntactic decision task.

These results suggest that the continuous lexical decision task is a measure which may be sensitive to parsing decisions. If the task reveals parsing processes reliably, but a few words later, it can be used in conjunction with the syntactic decision task. The lexical decision data may support the syntactic decision results with valuable shorter decision times. Alternatively, the task itself may encourage a different kind of processing altogether. Further use of the tasks together should reveal whether these apparent lags are reliable indicators of syntactic processing.

Experiment 2

Syntactic Decisions on Short Direct Object/Complement Clause Ambiguities

Experiment 2 was designed to measure the processing of direct object/complement clause ambiguities over short ambiguous regions. The parser may use a different strategy of ambiguity processing for each type of ambiguity. Direct object/complement clause materials do not generally cause conscious "garden-path" experiences the way main verb/complement clause ambiguities sometimes do. Therefore, the expectation that they would

be serially processed is much weaker.

If the direct object/complement clause ambiguity is parsed serially, then an increased decision time at the disambiguating word would be expected only for the ambiguous sentence with the complement clause (non-minimal attachment) resolution. If the the parser is operating using a parallel strategy, both ambiguous sentences (they are the same prior to disambiguation) should show an increased load in the ambiguous region, starting at the first word of the ambiguous region, and remaining high until the disambiguating word, where the incorrect parse is passively dropped and only the single correct structure is carried along. The delay model predicts a gradual increase in processing load across the ambiguous regions. Maximal load should occur at the disambiguating word when the postponed work of parsing is begun. Thus the critical difference between the predictions of the parallel and delay models concerns the disambiguating word. If the parser is modular, animacy of the noun in the ambiguous region will not have a significant effect on parsing strategy or difficulty. Animacy will be discussed further below.

Method

Subjects

Twenty four Hunter College undergraduates participated and were remunerated with extra credit points. None of the subjects had participated in either of the earlier experiments. All data from subjects with errors in more

than two of the eighteen experimental sentences were discarded and replaced. One subject was omitted from the final data analysis because of errors on every example of a given type of sentence. All eighteen sentences were included in the final analysis. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Materials

The materials consisted of eighteen sentence sets, each with a two word noun phrase which served as the ambiguous region. The main clause verbs of the experimental sentences were complex verbs compatible with either direct object noun phrases or complement clauses as arguments. Both ambiguous completions were tested. An unambiguous complement clause sentence was used as a control. In the ambiguous sentences, only the two word noun phrase appeared between the ambiguous verb and the resolution. The control sentence contained the complementizer "that" before the complement clause. The animacy of the noun in the noun phrase was also manipulated in order to see if animacy of the noun in the ambiguous region has an effect on structural preference. The animate and inanimate nouns were matched for length and frequency and were plausible both as subjects and objects.

A complete sentence set thus consisted of six sentences. In the example

set that follows, the ambiguous regions are underlined and disambiguating words are immediately preceded by a pound sign. Words which make a sentence structurally unambiguous are in bold type. Coding in parentheses preceding each sentence shows first its resolution or ending type (complement or transitive), then its ambiguity status (ambiguous or unambiguous), and finally whether the noun in the ambiguous region is animate (A) or inanimate (I).

(COMP/AMB/A) The detective revealed the burglars #were now out of the country

(COMP/UNAMB/A) The detective revealed **that** the burglars were now out of the country

(TRANS/AMB/A) The detective revealed the burglars #when he threw back the curtain

(COMP/AMB/I) The detective revealed the jewels #were now out of the country

(COMP/UNAMB/I) The detective revealed **that** the jewels were now out of the country

(TRANS/AMB/I) The detective revealed the jewels #when he threw back the curtain

Note that the complement control sentence is identical to its ambiguous counterpart at every word except the complementizer. The transitive version is only equivalent to the other sentences before the disambiguating word. Beginning at the disambiguating word, subjects are responding to words that differ from those in the complement versions, and differences in response

time which occur in those positions may be due to lexical rather than syntactic effects. As before, periods were not used in order to avoid cuing subjects that they had reached the end of a sentence. Subjects received only one sentence from a set, eighteen experimental sentences in all. These were intermixed with sixty filler items with a variety of lengths and structures, about half of which were ungrammatical at some position in the fragment.

Procedure

The task was the continuous syntactic decision task described above in experiment 1.

Results and Discussion

The data were tested with two 4-way analyses of variance using both subjects and materials as random effects (Clark, 1973) in a repeated measures design. The random effect for each analysis was crossed with type of sentence (3 levels: ambiguous direct object, ambiguous complement clause, or unambiguous complement clause with complementizer), animacy of noun (animate or inanimate) and sentence position (1-6). The positions measured were the verb (position 1), the determiner (position 2), the noun (position 3), the disambiguating word (position 4), the word just following the disambiguating word (position 5) and the last word of the sentence (position 6).

The grand mean syntactic decision time for the experiment was 767 ms.

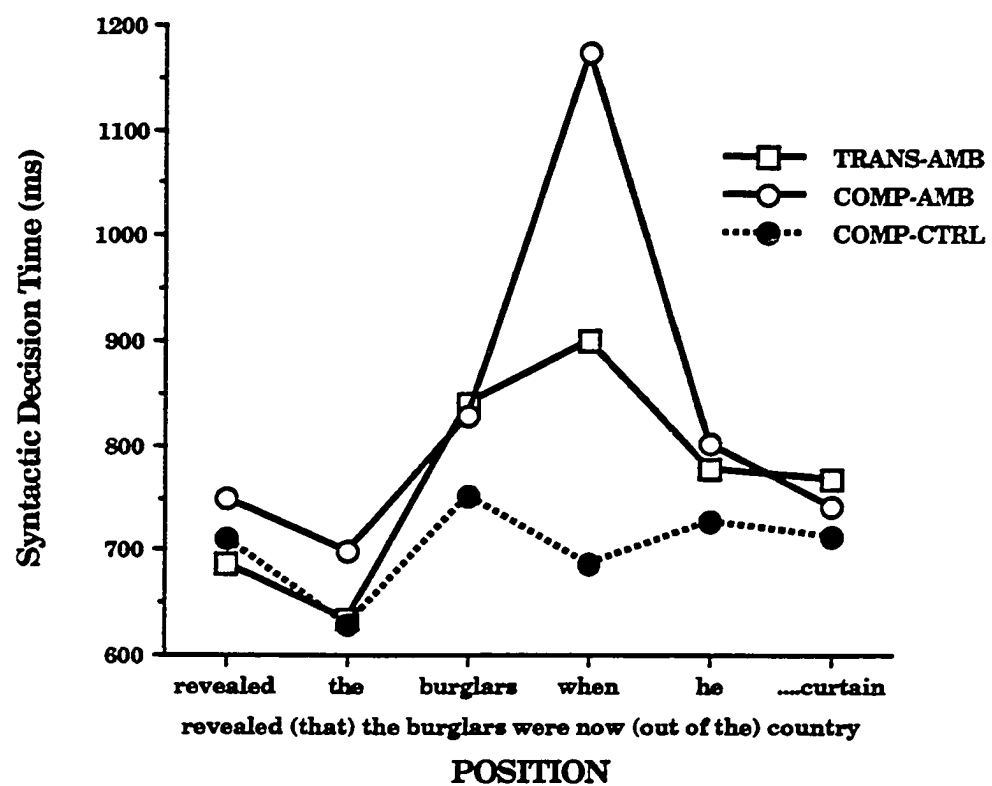
Word position was highly significant in both analyses: $F_1(5,110) = 9.44$, $p <$

.0001 and $F_2(5,85) = 7.36, p < .0001$. Once again, the main effect for word position confirms that subjects were actually reading the sentence. Sentence type was also significant as a main effect: $F_1(2,44) = 3.48, p < .05$ and $F_2(2,34) = 8.88, p < .001$ showing that overall the sentences differed in their difficulty. Since ambiguity status was not fully crossed with ending type in this design, the interaction of interest for parsing strategy was simply sentence type by word position, using the three versions of the sentence as the separate ending types. This interaction was clearly significant: $F_1(10,220) = 2.08, p < .03$ and $F_2(10,170) = 4.18, p < .0001$, showing that processing loads across the sentences followed different patterns in each version. This interaction will be discussed in greater detail below. Animacy was not significant as a main effect or in any interaction, consistent with parser modularity.

The mean decision times for the interaction of sentence type and word position are shown in figure 5. There is a slight increase in processing load across the ambiguous region of both ambiguous sentences, with the greatest processing difficulty at the disambiguating word in the complement version.

The difference in processing load between the ambiguous complement version and the complement control sentence at position four (the disambiguating word) is significant ($p < .01$) in a Duncan Multiple Range test. Since subjects are responding to a different word in the transitive

Figure 5: Experiment 2
Direct Object/Complement Clause Ambiguities



sentences, a comparison of this type cannot be made for those sentences at that position.

Analysis of the pattern of errors (Table 2) shows that the frequency of nongrammaticality judgments is not equally distributed across all possible positions in the sentence: $\chi^2(6) = 22.15, p < .01$. There is a notably higher frequency of errors at position four (the disambiguating word) in the ambiguous complement sentences. This cell monitors the number of subjects who were garden pathed.

These results can be interpreted in two ways. The data provide weak support for the delay model, because of apparent though nonsignificant increases in processing load across the ambiguity which are largest at the disambiguating word. However, the results are also compatible with the serial model, since the only statistically significant difference was at the disambiguating word in the nonpreferred version of the sentence compared to its unambiguous control at that position. The size of the increase at the disambiguating word in the transitive version is difficult to interpret with this design because subjects are responding to a different word at that position. Whether the slight increase can be attributed to lexical differences or to syntactic ambiguity can only be resolved by adding a transitive control sentence.

As a first approximation to a solution, transitive control sentences were run as some of the filler items in another experiment. These sentences used

Table 2

Number of "Ungrammatical" judgments from experiment 2 by position

	Position			
	BEFORE AMB.	AMB. REGION	DISAMBIG.	TO END
COMP-AMB	0	1	23	0
COMP-CTRL	1	0	3	1
TRANS-AMB	0	2	7	6

simple verbs (verbs consistent with only the direct object argument). The verbs were matched as closely as possible for length and frequency with the complex verbs. For example, the control sentences for the above example were:

(TRANS/UNAMB/A) The detective **spotted** the burglars when he pulled back the curtain

(TRANS/UNAMB/I) The detective **spotted** the jewels when he pulled back the curtain

The results for these were then patched in with the results for the three original conditions for a rough look at what a complete design might have revealed. Only a sentence analysis was done, because different subjects saw different versions of the sentences in an incompletely nested design. There was a significant main effect for word position ($p < .0001$), and significant two-way interactions for ending type by word position ($p < .01$), ambiguity status by word position ($p < .001$), and ending type by ambiguity ($p < .0001$). The interesting three-way interaction, ending type by ambiguity status by word position, was also significant, $p < .01$. Although these ANOVA results appear very promising, a graph of the means revealed that the patch behaved disappointingly. At nearly every position, the control version took longer to process than the ambiguous version. This result was attributed to poor experimental design and the experiment was replicated, running all conditions simultaneously with an appropriately crossed design.

Experiment 2a

Syntactic Decisions on Short Direct Object/Complement Clause Ambiguities

This experiment is essentially a replication and correction of experiment 2. An additional two transitive control sentences (animate and inanimate) were added to each materials set for a fully crossed design with improved controls.

Method

Subjects

Thirty two Hunter College native English speaking undergraduates participated, for the usual "extra credit" remuneration. None of the subjects had participated in any of the previous experiments. Four subjects were replaced for having four or more errors in the experimental materials. One subject's data were deleted from the subject analysis because all examples of a sentence type contained errors and thus no mean for that condition for that subject could be obtained. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Materials

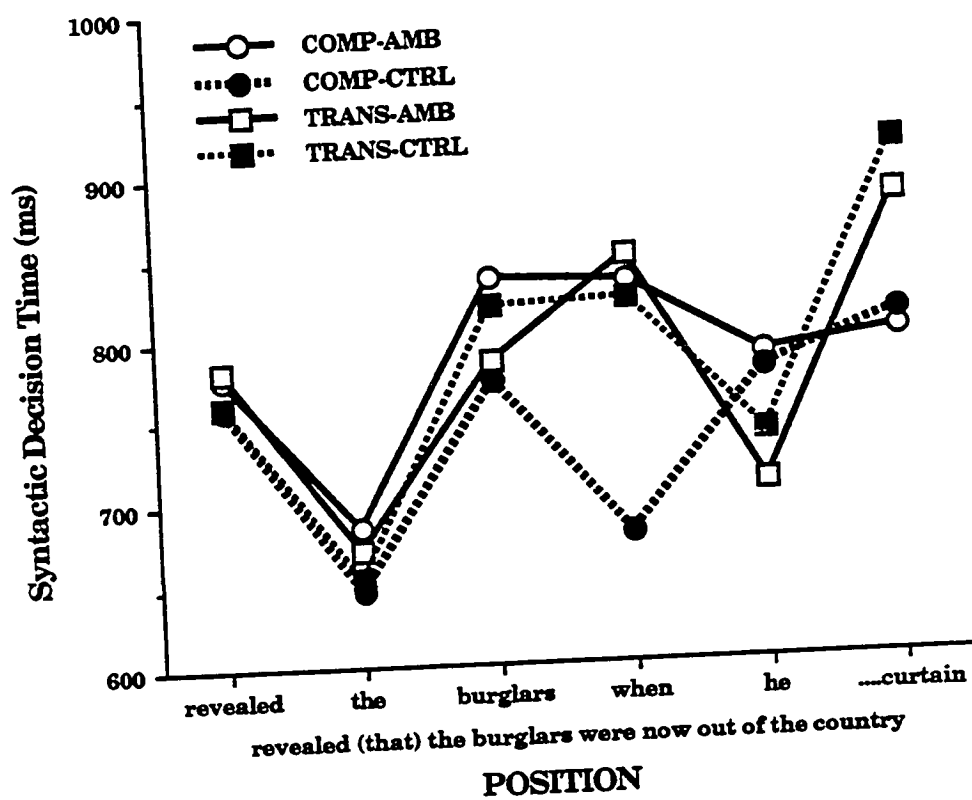
All eight versions of the complement/transitive, ambiguous/unambiguous, animate/inanimate experimental sentences used

in the previous two incomplete experiments were used in a fully crossed design. A total of sixteen sentence sets were constructed. The transitive controls used verbs which, as described above, were matched as closely as possible for length and frequency with the complex verbs in their sentence sets.

Results and Discussion

The grand mean syntactic decision time for all the data was 772 ms. Word position was a highly significant main effect: $F_1(5,150) = 16.98, p < .0001$ and $F_2(5,75) = 10.19, p < .0001$. The sentence ending by word position interaction was also significant: $F_1(5,150) = 3.74, p < .005$ and $F_2(5,75) = 3.19, p < .02$. However, the three-way interaction of interest, sentence ending by ambiguity status by word position was not significant in either analysis. (See figure 6). This interaction tells whether ambiguity affects processing loads across the sentence differently in the two resolutions. Although not statistically significant, some salient features of the graph of these means can be noted. At the disambiguating word, the ambiguous complement version has a longer mean decision time than the same word in the unambiguous complement version. This difference is much smaller one word sooner, at the second word of the ambiguous region, but in the same direction, suggesting serial processing or weakly suggesting delayed processing. At the disambiguating word, the ambiguous transitive version

Figure 6: Experiment 2a



takes very slightly longer than the same word in the unambiguous sentence. This was the comparison missing from the original study. Although the direction is consistent with predictions of the delay model, the magnitude of the difference is extremely small.

Analysis of the error rates (see table 3) shows a very high rate of "ungrammatical" judgments at the disambiguating word in the ambiguous complement sentences (the garden path condition). The second highest error rate occurs in the same position in the ambiguous transitive sentences. High error rates at the disambiguating word in the garden path condition imply that a serial analysis is taking place. However, a concurrent increase in errors in sentences with the preferred ending weakens this implication. It could be that the materials are being serially parsed, but that there are individual differences between subjects in their structural preferences. A test for homogeneity of variances was performed at position four. Decision times on the disambiguating word in the complement resolution had significantly more variability than decision times for the corresponding word in the unambiguous context: $F(30,30) = 3.726, p < .01$. The difference between ambiguous and unambiguous transitive sentences at that position was not significant: $F(30,30) = 1.496, p > .05$. We can infer from these results that subjects are behaving similarly when the transitive disambiguating word is encountered, but that they are doing different things when the complement clause sentences are disambiguated. Evidently, only some

Table 3

Number of "Ungrammatical" judgments from experiment 2a by position

	Position			
	BEFORE AMB.	AMB. REGION	DISAMBIG.	TO END
COMP-AMB	0	1	10	1
COMP-CTRL	0	0	0	0
TRANS-AMB	0	0	3	0
TRANS-CTRL	0	0	2	7

subjects were garden-pathed, and others were not. This is evidence that there are differences between subjects in their structural preferences. For this analysis, verbs were not separated on the basis of their lexical biases. Numbers used for each subject (in each condition) were mean decision times for that subject, at that position, across all sentences of a given type. Experiment 5 will address the issue of structural biases of verbs. This finding of between-subject differences in preference is evidence against the generality of the minimal attachment rule.

Experiment 2b

Lexical Decisions on Short Direct Object/Complement Clause Ambiguities

The continuous lexical decision task was used on the same materials to see if the pattern of results obtained with the syntactic decision task occurs with shorter decision times.

Method

Subjects

Thirty two Hunter College native English speaking undergraduates participated, for the same kind of "extra credit" remuneration. None of the subjects had participated in any of the earlier experiments. Error rates were low and all 32 subjects and 16 sentences were included in the statistical analysis of the data. Prior to data analysis, decision times greater than two

standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Materials

Experimental materials from experiment 2a were reused without alterations. Only filler items were changed such that items which had ended ungrammatically in experiment 2a now ended with nonwords.

Procedure

Presentation of the stimuli was identical to presentation in the previous experiment. However, instead of a grammaticality judgment on each word, subjects made a lexical decision on each word.

Results and Discussion

The grand mean lexical decision time was 532 ms. As in the other experiments, word position was a highly significant main effect: $F_1(5,155) = 50.63, p < .0001$ and $F_2(5,75) = 11.44, p < .0001$ verifying that the subjects were certainly reading and responding to the words and not mechanically pressing the response keys. This main effect is especially valuable when the experimental effects of interest are not obtained. When word position is highly significant, it is not likely that negative results are due to subjects' inattention to the task. The only significant interaction obtained was sentence resolution by word position, and this was only significant in the subjects analysis: $F_1(5,155) = 2.84, p < .02$. The interaction of interest for

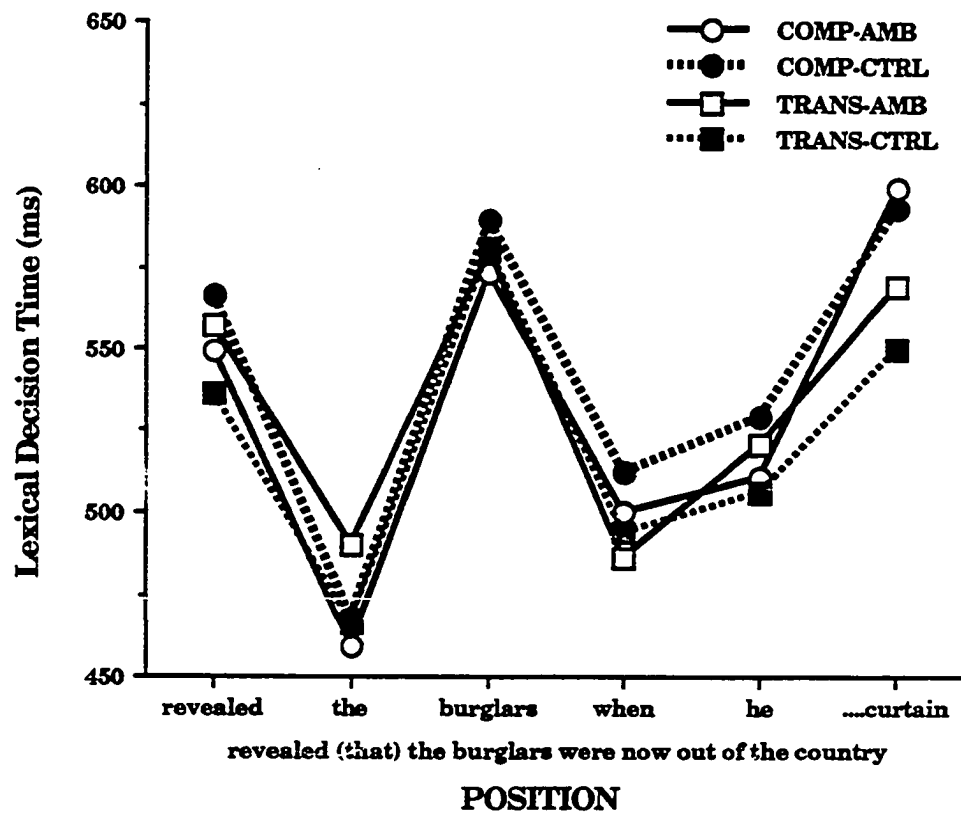
parsing strategy, sentence resolution by ambiguity status by word position, was not significant. A graph of the means (Figure 7) shows that all conditions follow approximately the same pattern: increased decision times at the noun and at the last word. This increase may be based on lexical (word frequency) properties rather than structural ones. Because all the test materials showed the same pattern of processing load changes across the entire sentence, regardless of whether ambiguity was present or how the sentence was finally resolved, the results of this experiment are not informative about parsing strategy.

Experiment 3

Syntactic Decisions on Long Direct Object/Complement Clause Ambiguities

Experiment 3 was designed to track processing loads over a longer time course. The results of the previous syntactic decision experiment could be interpreted to support either serial processing or delayed processing. The results of the lexical decision task did not resolve the question. The materials for this experiment are designed to test the parser's behavior over a longer ambiguous region. Does the parser operate serially, or does it delay processing all the way to disambiguation no matter how far away the sentence is resolved? If the parser only delays temporarily, when does it default to assignment of the preferred structure? Assuming that the parser follows

Figure 7: Experiment 2b



rules of minimal attachment and that it is operating serially, then the only location where an increased processing load is expected is at the disambiguating word in the nonpreferred version. For these materials with extremely long ambiguous regions, the disambiguating word occurs at position nine. If the parser is holding both possible structures in parallel during the ambiguity, an increased load relative to the unambiguous versions is expected across the entire duration of the long ambiguous region. Alternatively, if the system is only momentarily parallel, the increased load will be observed for only the first part of the ambiguous region. If the latter is the case, the heavy load should return to normal levels before disambiguation when the parallel strategy is abandoned, and then show the serial processing peak in only the nonpreferred ending at the disambiguating word. The delay model predicts that there will be a gradual increase in processing load as the ambiguity progresses, but that memory limits for unprocessed material will force the parser to select a preferred analysis and operate serially after a small number of words. At the disambiguating word, the pattern of results would be like those the serial or momentary parallel models predict. Thus, the distinction between results expected for a momentary parallel or temporary delay model is not clearcut.

Method

Subjects

Thirty two Hunter College undergraduates participated and were

remunerated in the usual way. None had participated in any earlier experiments. All data from subjects with errors in more than two of the sixteen experimental sentences were discarded and replaced. Thirteen subjects were omitted from the final data analysis because of errors on every example of a given type of sentence. One sentence was omitted from the final analysis because every subject exposed to one or more versions of that sentence made an error. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Materials

The sentences from experiment 2b were modified to contain longer ambiguous regions. The two word noun phrase was extended to 7 words. This extension was identical for all members of a sentence set. An example of one member of a sentence set follows. The ambiguous region is underlined and the disambiguating word is immediately preceded by a pound sign.

The detective revealed the burglar from the famous museum heist #was now
out of the country

The manipulation of animacy was maintained to observe the effects of animacy over a longer time course.

Procedure

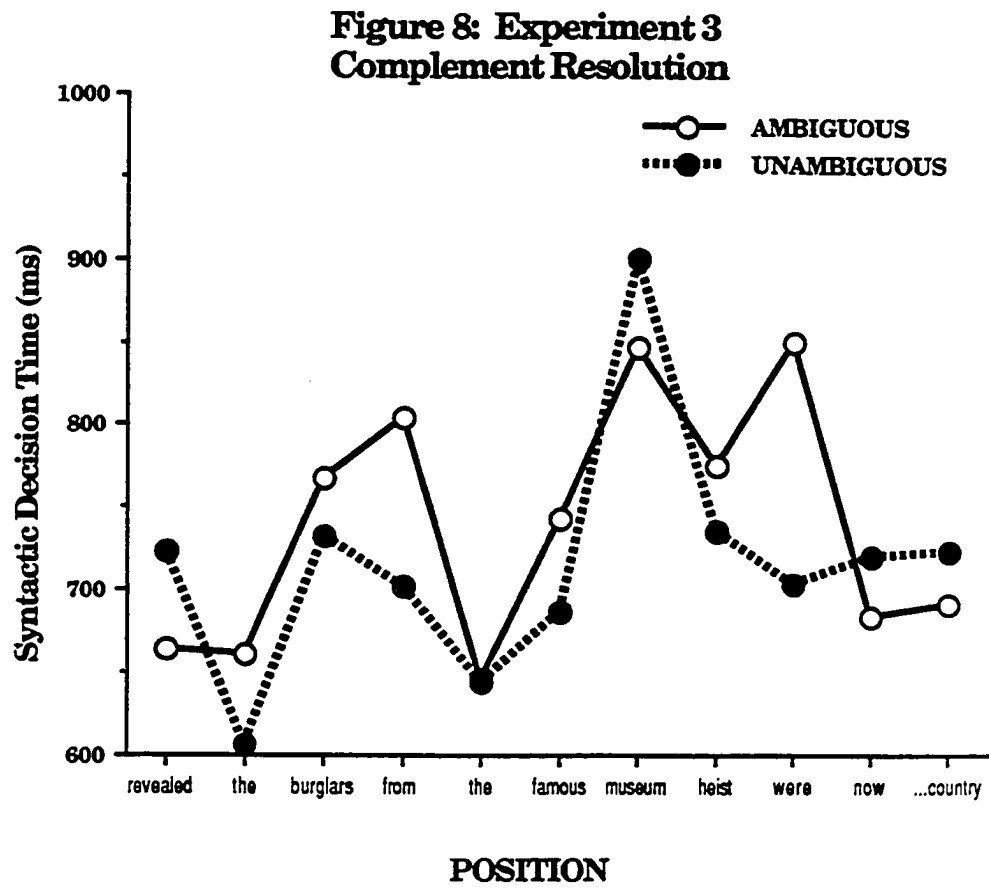
The procedure was the continuous syntactic decision task, as described

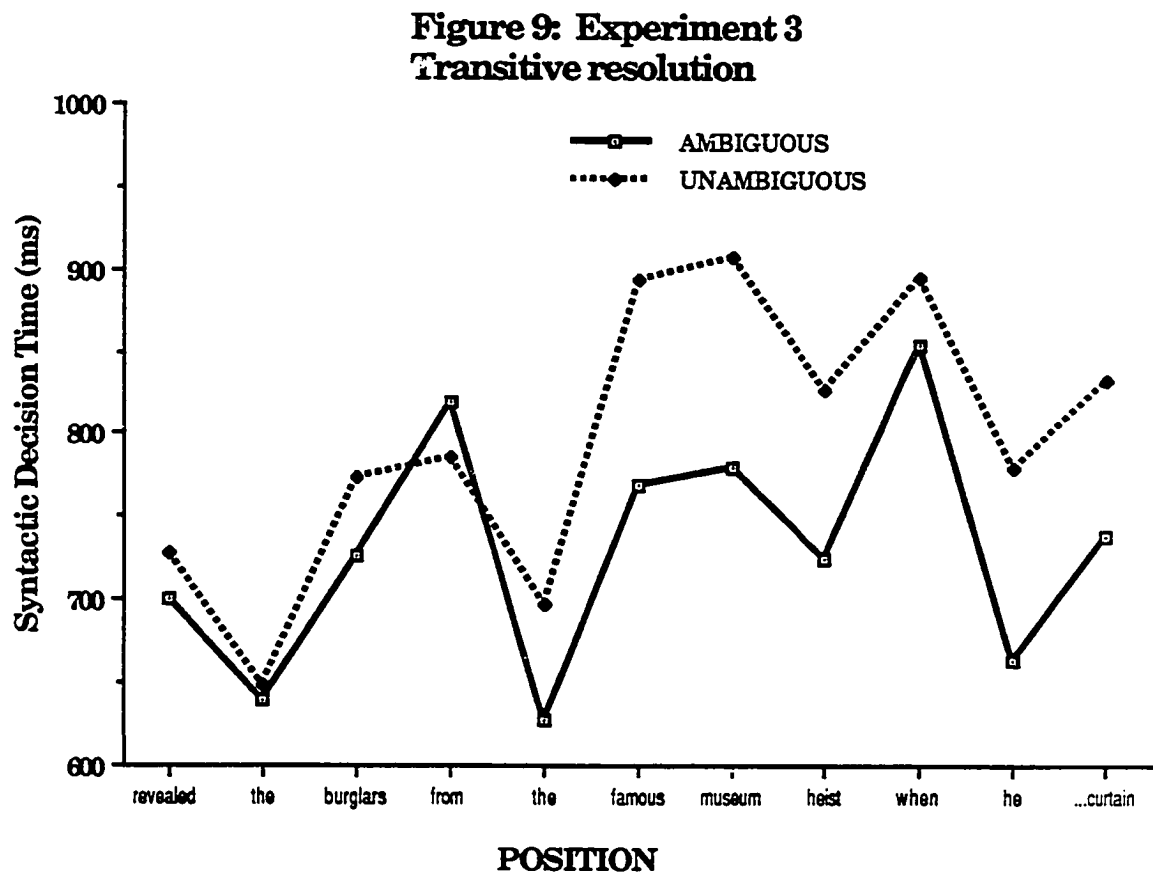
in experiment 1.

Results and Discussion

The grand mean syntactic decision time was 751 ms. As in previous experiments, word position was highly significant: $F_1(10,180) = 8.03$, $p < .0001$ and $F_2(10,140) = 7.0$, $p < .0001$. The two-way interactions, sentence ending by word position ($F_2(10,140) = 2.0$, $p < .05$), and ambiguity status by word position ($F_2(10,140) = 2.71$, $p < .01$), were significant only in the materials analysis. Animacy continued to fail to be significant as a main effect or in any interaction. The three-way interaction of primary interest, sentence ending by ambiguity status by word position, was not significant in either analysis. However, examination of the means reveals some interesting trends. (See figures 8 and 9).

In the complement sentences alone (Figure 8), the ambiguous version does show a small increased load in the first three words of the ambiguous region relative to the unambiguous control. This small increase seems to disappear for the rest of the ambiguous region, and reappear at the disambiguating word. The increase at the disambiguating word is not present in the ambiguous version of the transitive sentence (Figure 9) in comparison to the transitive control sentence. Although these differences are extremely small, the directions of the differences correspond to those predicted by the temporary delay model.





Experiment 3a

Lexical Decisions on Long Direct Object/Complement Clause Ambiguities

Even when the findings of a syntactic decision task have been strong, as in Experiment 1, the lexical decision task (Experiment 1a) only weakly followed the pattern of results, albeit with shorter decision times. Typically, the direction of results from the two tasks is similar, but the magnitude of the obtained processing differences is much smaller in the lexical decision task results. In experiment 3, the syntactic decision results were weak. It is possible that the pattern of results will be replicated in the lexical decision task, and offer another instance of a pattern of small changes which are directionally consistent with the results predicted by the temporary delay model. It is also possible since the lexical decision task has been less sensitive to parsing processes than the syntactic decision task, that no information about parsing strategy will be obtained from the experiment.

Method

Subjects

Thirty two Hunter College undergraduates participated and were remunerated with extra credit points. No subject had participated in any earlier experiment. Error rates were low and all 32 subjects and 16 sentences were included in the statistical analysis of the data. Prior to data analysis,

decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Materials

The same expanded material set used in experiment 3 was used. Filler stimuli were changed to contain nonword rather than nongrammatical items.

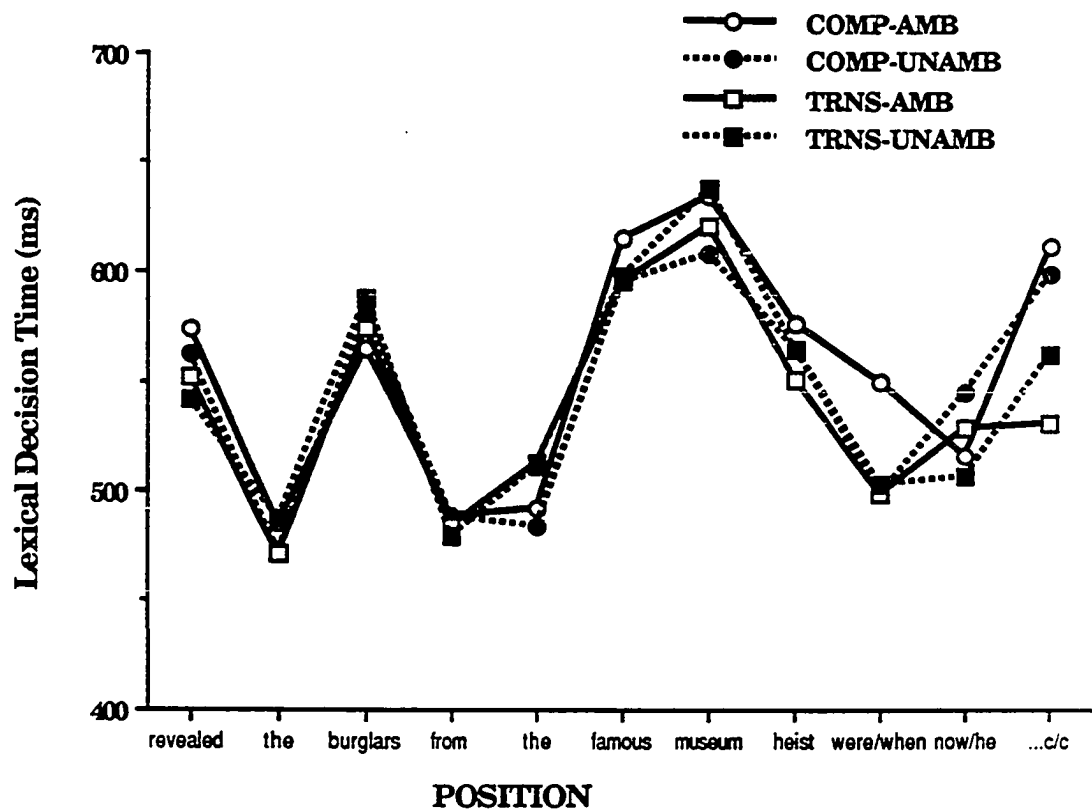
Procedure

The continuous lexical decision task described in experiment 1a was used to test for task-independence of the findings of experiment 3.

Results and Discussion

The grand mean lexical decision time was 545 ms., again notably shorter than the syntactic decisions on the same materials. The main effect for word position was highly significant: $F_1(10,310) = 26.8, p < .0001$ and $F_2(10,150) = 8.01, p < .0001$. The interaction of sentence ending by word position was also significant: $F_1(10,310) = 1.92, p < .05$ and $F_2(10,150) = 2.06, p < .05$ implying that the two sentence endings cause different patterns of processing load during parsing, regardless of ambiguity status. The three-way interaction of sentence ending by ambiguity status by word position approached significance ($p < .06$ for both materials and subjects analyses). The means for this interaction are shown graphically in figure 10. All four

Figure 10: Experiment 3a



sentences appear to follow the same processing pattern up until position nine (the disambiguating word). There, only the ambiguous complement clause version diverges slightly from the others, showing an increased load. A finding of increased load in the non-minimal attachment version at the disambiguating word is generally used to support the serial model, but the magnitude of the difference obtained here is very small.

Experiment 4

Syntactic Decisions on Sentences with Complement Endings, whose
Noun Phrases are either Plausible or Implausible as Direct Objects

In all experiments reported so far, parser modularity has been supported. Experiment 1 and 1a indicated that the parser does not attend to pragmatically biasing context in its selection of a main verb or passive participle reading of an ambiguous phrase. Experiments 2, 2a, 3 and 3a showed that animacy of the noun in the ambiguous region did not affect parsing strategy. In the previous experiments, both animate and inanimate nouns were carefully selected to be plausible in either syntactic context: as direct objects or subjects of upcoming complement clauses. In this next experiment (#4), plausibility of the nouns as direct objects of the verb was directly manipulated. If the nouns were extremely implausible as direct objects, would the parser treat the ambiguous phrase as a functionally

unambiguous predictor of a subsequent complement clause?

Since all the preceding results have been consistent with the modularity thesis, the initial prediction was that pragmatic plausibility of the noun phrase would have no effect on parsing decisions. If the parser is sensitive to pragmatic plausibility and utilizes this kind of information in its analysis, then the parser should be cued that a complement clause is forthcoming if the noun in the ambiguous region is implausible as a direct object. This functional disambiguation should be evidenced by a lack of difference in processing load between the ambiguous and unambiguous versions of the sentences containing the implausible noun. The noun which is plausible with either structure will not give the parser this cue that a complement clause is expected, and the increased processing load at the disambiguating word in the sentence without the complementizer should be present, as it was in experiment 2.

Method

Subjects

Thirty two Hunter College undergraduates participated and were remunerated in the usual way. None of the subjects had participated in any earlier experiment. All data from subjects with error rates in experimental materials above two per eighteen were discarded and replaced. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard

deviations above the mean for that subject.

Materials

New materials were constructed which used complex verbs compatible with direct object or complement clause arguments. Since the noun phrases were highly implausible as direct objects, only complement clause endings were tested. Short ambiguous regions were used because of the relative lack of success with the longer ambiguous regions in experiments 3 and 3a. A typical sentence set follows. As before, ambiguous regions are underlined, disambiguating words are preceded by a pound sign, and the words which make the sentence structurally unambiguous are presented in bold type. The coding in parentheses before each sentence indicates first its ambiguity status, and second the plausibility of the noun as a direct object of the verb.

(ambiguous/plausible as D.O) The reporter believed the editor #was unusual

(ambiguous/implausible as D.O) The reporter believed the cake #was unusual

(unambiguous/-) The reporter believed **that** the editor was unusual

(unambiguous/-) The reporter believed **that** the cake was unusual

Each sentence set contained only four sentences. Although it was not intuitively clear whether implausibility of the noun as a direct object would affect sentences whose complement clause was unambiguously introduced, these sentences were included to complete the controls for the set. Eighteen such sentence sets were constructed with plausible and implausible nouns matched for length and frequency.

Procedure

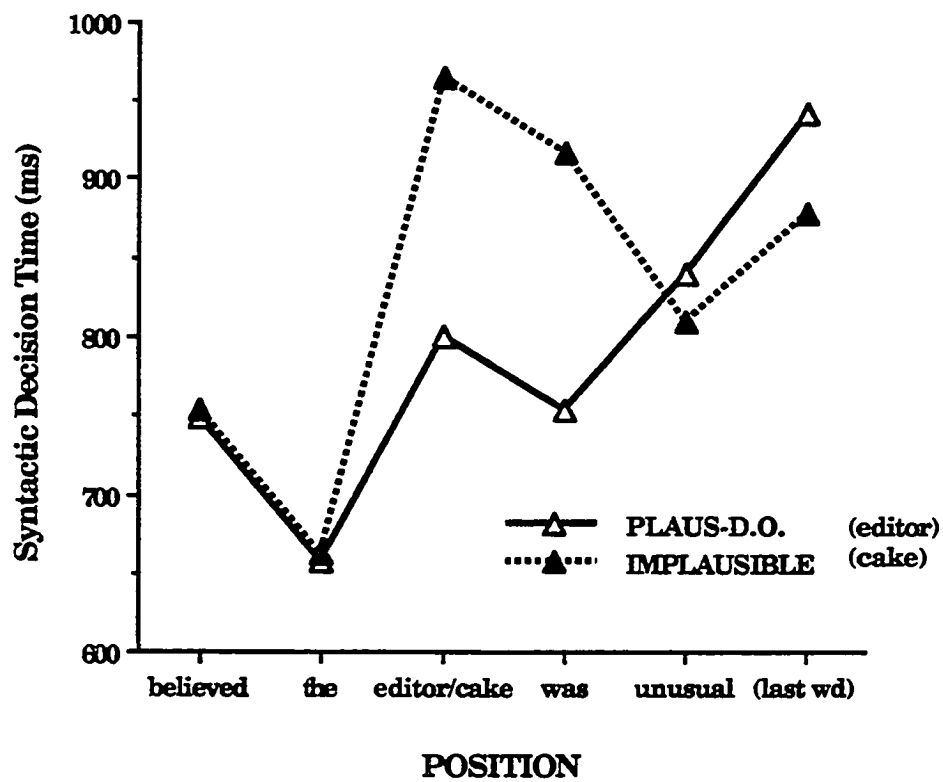
These materials were tested using the continuous syntactic decision task described above.

Results and Discussion

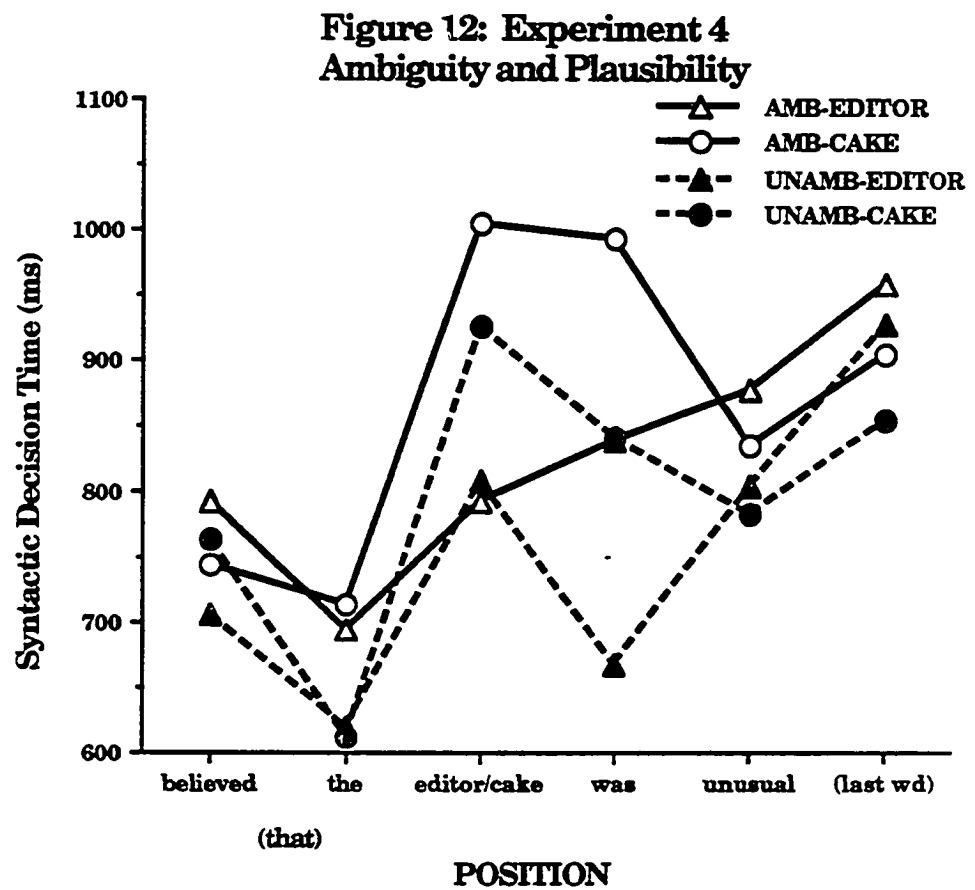
The grand mean syntactic decision time for the experiment was 810 ms, longer than for the previous experiments. The grand mean can be considered a rough index of task difficulty, indicating that subjects found these materials more difficult than previous ones. Consistent with previous results, word position was highly significant: $F_1(5,115) = 13.02, p < .0001$ and $F_2(5,85) = 8.23, p < .0001$. There was a main effect for ambiguity as well: $F_1(1,23) = 26.61, p < .0001$ and $F_2(1,17) = 6.97, p < .02$, with longer decision times on words in ambiguous sentences (845 ms) than in unambiguous sentences (775 ms). The interaction of noun plausibility and position was significant: $F_1(5,115) = 4.25, p < .002$ and $F_2(5,85) = 3.29, p < .01$. This means that without considering ambiguity, there were differences in how sentences with plausible or implausible nouns were processed. However, the more important interaction for analysis of the way plausibility affects parsing strategy, the three-way interaction of ambiguity status by noun plausibility by word position, was not significant.

The means from the significant interaction are shown graphically in figure 11. The primary location of the difference between the sentences with

Figure 11: Experiment 4
Plausibility of noun as direct object



nouns plausible only as subjects of complement clauses and the sentences with nouns that are plausible in either syntactic context occurs at the noun itself rather than at the disambiguating word. Since at this position, subjects are responding to different words, it is possible that there are lexical effects operating at the noun (position three) which may carry over to the disambiguating word (position four) as well. To sort out simple lexical effects from the syntactic ones of more interest here, the nonsignificant three-way interaction was examined (see figure 12). Here it is clearer that two separate processes are going on. At position three, lexical effects separate the implausible nouns from the plausible ones, for both ambiguous and unambiguous versions. These lexical effects may be frequency related, or even be showing results of lexical priming, since the plausible nouns may be partially activated by previous words in a way that the implausible nouns were not. In the given example, the word "reporter" would prime "editor" more than "cake". However, at the disambiguating word, a syntactic effect of ambiguity appears also to be present, with ambiguous versions of either sentence higher than their unambiguous controls at position four. For both ambiguous sentences, processing load increases throughout the ambiguous region and remains high at the disambiguating word, consistent with the delay model. Holmes, Stowe and Cupples (in press) also obtained an effect for noun plausibility occurring at the noun itself. Their work will be discussed in more detail below in the bias analysis for this experiment.



Experiment 5

Questionnaire on Structural Biases for Specific Complex Verbs

Clifton, Frazier and Connine (1984) reported evidence that structural preferences of complex verbs influence the strategy the parser uses to process ambiguities which follow. They tested verbs which were predominantly transitive or intransitive, and found that responses on a secondary lexical decision task were faster when the material following the verb matched the preferred frame. Mitchell and Holmes (1985) sorted complex verbs by structural preference established by sentence completion for direct object or complement clause arguments as part of a much larger experiment testing several forms of ambiguity processing. They formed six sentence pairs using a verb from each preference group in an identical sentence frame. All of the direct object/complement clause ambiguities were resolved with complement clauses. Reading times for the disambiguating region were compared within each pair depending on the structural bias of the verb preceding the ambiguous region. In four of the six sentence pairs, reading times for the disambiguating region were longer for complements following transitive-biased verbs. In the remaining two sentence pairs, reading times for the complement disambiguating region were longer for the clausal-biased verbs.

Before the effects of structural preference of the verbs used in the preceding experiments could be tested, the verbs had to be sorted on the basis of structural preference. The purpose of experiment 5 was to obtain structural preference data for these verbs. The verbs were not presented in isolation as in Clifton, Frazier and Connine (1984), or with neutral pronoun subjects as in Holmes, Stowe and Cupples (in press). Instead the previous experimental context was used, in case the semantic content of the sentence subject influenced structural preference. After the verbs were classified, the data from each experiment were reanalyzed with respect to these lexical biases as another test of the limits of parser modularity.

Method

Subjects

Twenty seven native English speaking subjects, naive to the purpose of the experiment were used. None had participated in any of the previous experiments. The subjects were various in origin: Hunter College students, band members from Kingsborough Community College, teachers from the Beechwood School on Long Island, and spouses of Biopsychology doctoral students completed the questionnaires.

Materials

The experimental materials consisted of pencil-and-paper questionnaires which listed only the subjects and verbs for each of the sixteen experimental sentences used in the experiments measuring direct

object/complement clause ambiguity. These beginnings of sentences were intermixed with 35 filler items which were also grammatical sentence beginnings consisting of three or four words. Each sentence beginning was followed by a long blank line on which subjects would write their own continuation of the sentence.

Procedure

Subjects had unlimited time to fill out the questionnaires. The instructions at the top directed them to complete every sentence using at least four more words. This instruction discouraged direct object completions chosen exclusively to minimize writing effort. Filler items were ignored in scoring. Responses following the verb in experimental sentences were classified at first pass into seven categories: direct object, tensed clause (with or without complementizer), infinitival clause with overt subject ("The mother expected her children to be home..."), wh- clause, other clause, infinitive ("The businessman forgot to bring his briefcase..."), and other. The last category included any completely ungrammatical responses.

Results and Discussion

The frequencies of response category for each verb are tabulated and shown in table 4. For simplicity and to match previous research technique (Mitchell and Holmes, 1985; Holmes, Stowe and Cupples, in press), only the two categories "direct object" and "tensed clause" were used in classifying verbs as individually biased toward either transitive or complement clause

Table 4

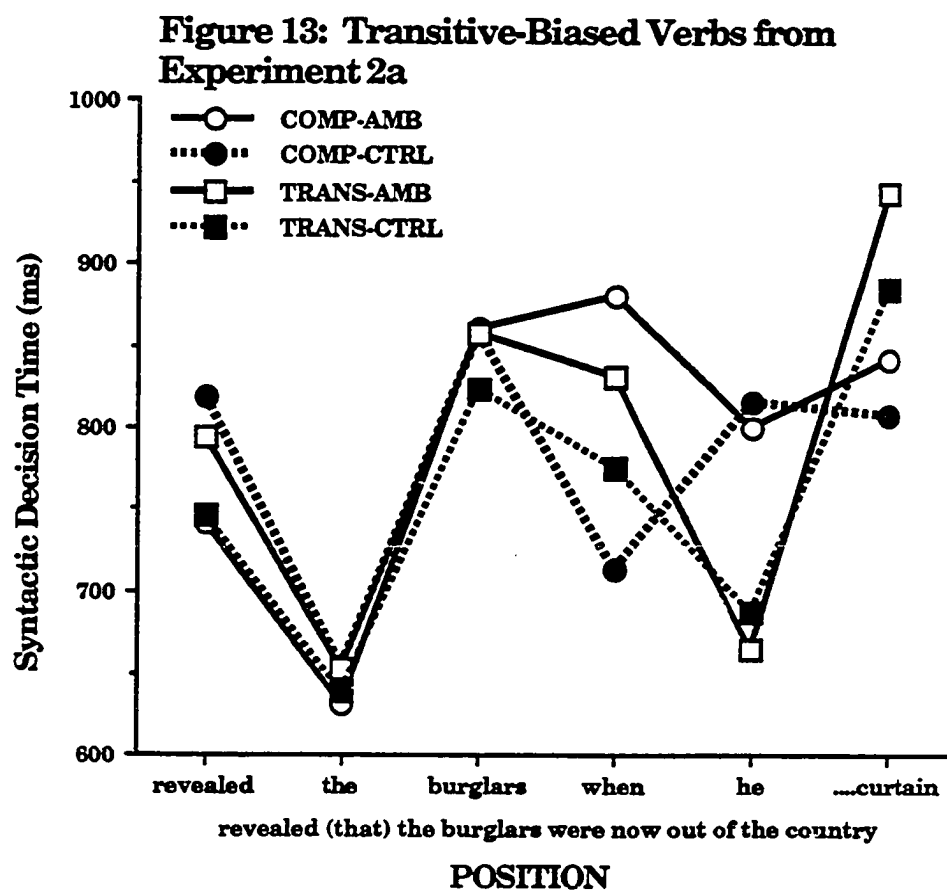
VERB BIAS CLASSIFICATIONS

TYPE OF ENDINGS PROVIDED BY SUBJECTS FOR EACH VERB

	DIRECT OBJECT	TENSED CL.	INF. CL.	WH-CL.	OTHER CL.	INF.	OTHER
FORGOT	8	3	0	1	0	13	2
DEMANDED	19	2	6	0	0	0	0
NOTICED	4	19	1	0	1	0	2
REVEALED	14	11	1	1	0	0	0
REPORTED	6	14	0	1	0	0	6
IMAGINED	2	19	1	2	2	0	1
JUDGED	4	8	12	1	1	0	1
NOTED	8	18	0	0	1	0	0
REQUESTED	4	11	12	0	0	0	0
SAW	10	12	0	1	4	0	0
HEARD	10	5	5	0	5	0	2
DISCOVERED	13	12	1	0	1	0	0
RECALLED	22	2	0	2	1	0	0
EXPECTED	9	5	12	0	0	1	0
DOUBTED	8	16	0	3	0	0	0
BELIEVED	1	23	1	0	0	0	2
REMEMBERED	13	10	0	2	1	0	1
FOUND	7	6	9	0	2	0	3

endings. Of the sixteen verbs tested, eight conveniently fell into each category. The data from the previous experiments (excluding experiment 1 which tested a different form of ambiguity) were then reanalyzed with respect to verb-bias, to see if these verb frame preferences influence structural choices during parsing. The interaction which tests this is among verb-bias, sentence resolution, ambiguity status and sentence position, essentially the parsing interaction with the added feature verb bias. Each experiment's reanalysis for the effects of lexical structural preference will be discussed in turn below.

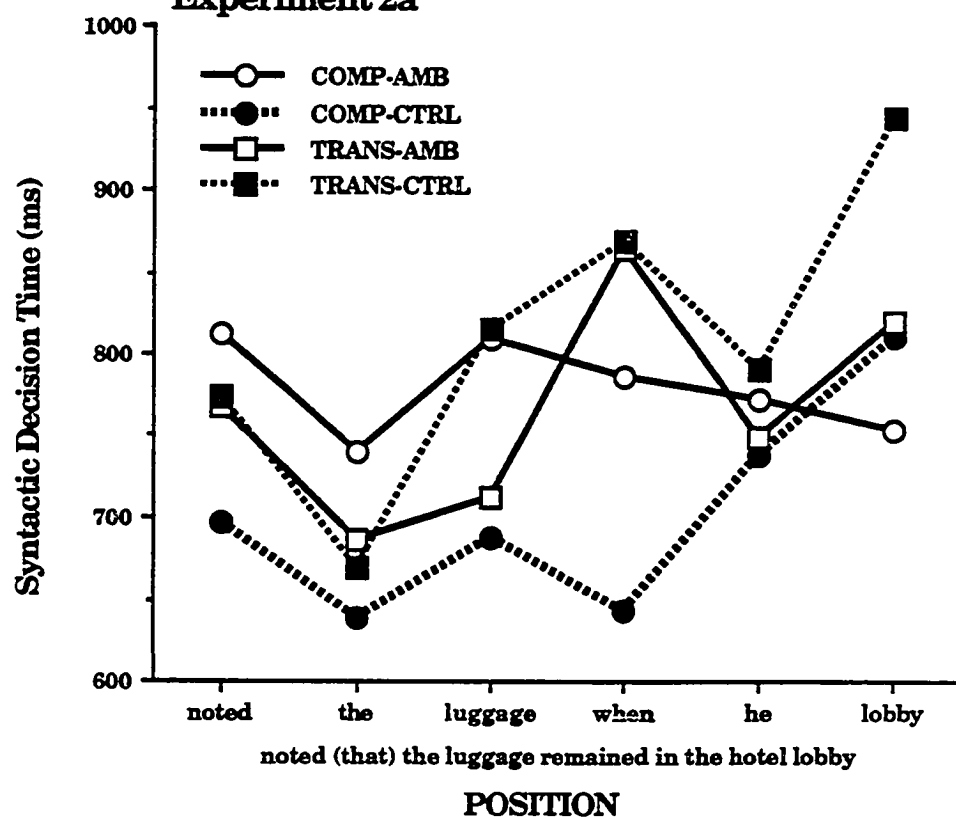
In the bias analysis for Experiment 2a, the four-way interaction, verb-bias by sentence resolution by ambiguity status by word position was not statistically significant: $F(5,70) = .79$, $p = .56$. However, the pattern of results for clausal-biased verbs does not appear to be identical to the one for the transitive-biased verbs. The pattern for the transitive-biased verbs appears to be serial (figure 13). All sentence versions are similar until the disambiguating word (position four), where they begin to diverge. The decision time is longest at the disambiguating word for the garden path condition (the ambiguous complement ending), and the complement control sentence has the shortest decision time at that position. Although the ambiguous transitive version does have a longer decision time than its control at the disambiguating word, the difference is very small. At the next word, lexical effects are operating alone, separating only each ending type



from the other. There are no longer any differences between the ambiguous and unambiguous versions. In the clausal-biased verbs (figure 14), the difference between the ambiguous and unambiguous complement versions at the disambiguating word is present but less pronounced. The ambiguous complement version has a longer decision time at the disambiguating word than the control complement sentence. The direct object sentences show no difference between ambiguous and unambiguous versions at position four. A relatively long time is taken to process that word in both ambiguous and unambiguous versions of the transitive sentences. So it is possible that the parser is more "surprised" when a complement clause is encountered after an ambiguity when the verb prior to the ambiguous region is more frequently followed by a direct object than when a complement clause is a common argument. According to this analysis though, the difference between strategies applied after each type of verb was not statistically significant. These findings are consistent with those reported by Holmes et al (in press) who obtained and discussed these kinds of apparent processing differences but did not test them for statistical significance.

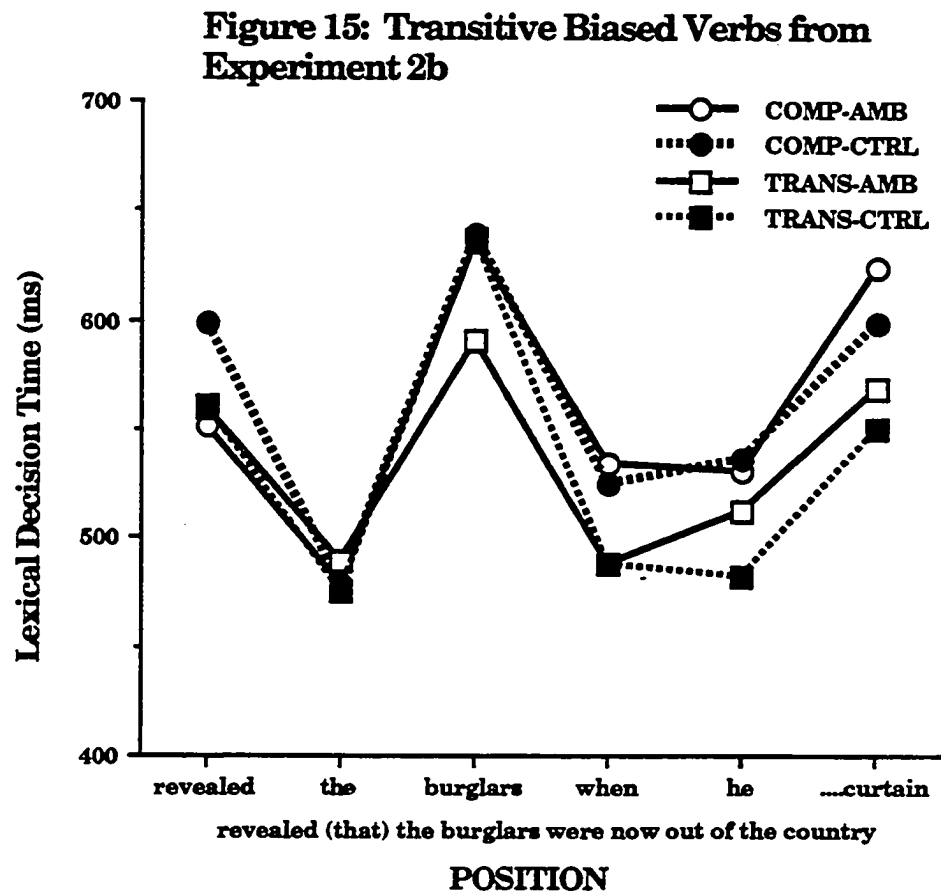
In the bias analysis for Experiment 2b, the lexical decision task on the same materials, the four-way interaction was not significant either ($F(5,70) = 1.16, p = .34$). The pattern of results of both verb-bias groups indicated that the differences in processing time between the sentences occurred as a result of responding to different words rather than to their structural contexts

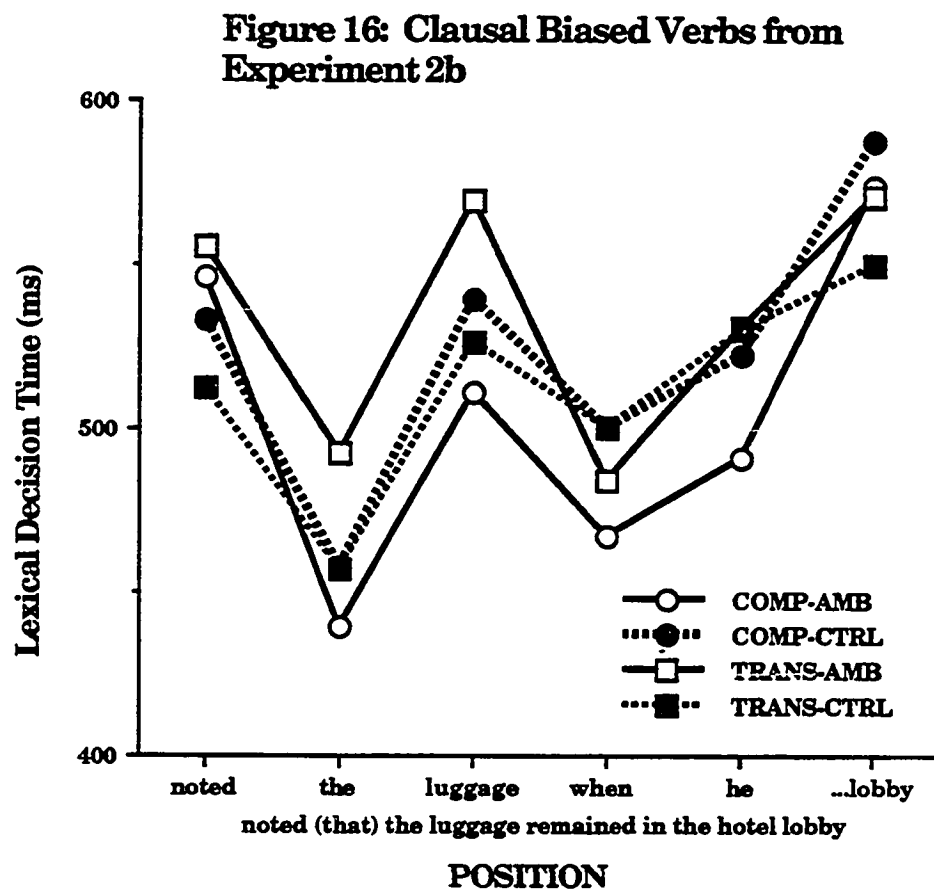
Figure 14: Clausal-Biased Verbs from Experiment 2a



(ambiguous or not). Figure 15 shows the direct object-biased verbs. Differences between the sentences begin to occur at the noun (position 3). At the disambiguating word, the four sentences are clearly separated into two pairs. If the longer two times were in the ambiguous versions, and the shorter two were the control versions, a statement about parsing could be considered. However, the slower two points at position four are in the two complement clause sentences (ambiguous and unambiguous) and the faster pair at that position belong to the two transitive endings. The difference between lexical decision times is very likely because subjects are responding to a different word at that position for each ending. This is apparent in figure 16, the pattern for the clausal-biased verbs, as well. Here, the differences between the versions are greatest at the noun, and at position four the ambiguous versions were actually faster than the control ones. It seems that the lexical decision task may be more sensitive than the syntactic decision task to lexical differences, which are the only notable differences seen in these results.

The data acquired from the materials with very long ambiguous regions (Experiments 3 and 3a) are difficult to interpret. In the syntactic decision task (Experiment 3), verb-bias did not interact significantly with sentence resolution, ambiguity status and word position. However, this interaction was significant in the materials analysis for the lexical decision task (Experiment 3a), $F_2(10,140) = 2.0, p < .05$. Unfortunately no meaningful





pattern is discernible from the analysis of either experiment. The difference between ambiguous and unambiguous complement versions at the disambiguating word is more pronounced in the clausal-biased verbs than in the transitive-bias group, exactly the opposite of what was reported just above for the shorter materials. This isolated significant result may be a type I error.

In experiment 4, all sentences were resolved with complement clauses. In the bias analysis for the materials measuring the effects of noun plausibility on parsing, the interaction of verb-bias with ambiguity status, plausibility of the noun as a direct object, and word position was not significant: $F(5,80) = .43, p = .82$. Figures 17 and 18 show the means of the transitive-bias group of verbs and the complement-bias group respectively. Both graphs show lexical effects operating at the noun, and ambiguity effects operating one word later at the disambiguating word. The word itself which is implausible as a direct object takes longer to process at position three than the more plausible word. At position four, the words following ambiguous regions have longer decision times than those which were unambiguously introduced. The garden path effect, the increased load at the disambiguating word for the ambiguous complement version compared to its complementized control, was about the same for the verbs more commonly followed by direct objects as for the ones more typically followed by complement clauses. These analyses were repeated, using only the five most extremely biased verbs in

Figure 17: Transitive Biased Verbs from Experiment 4

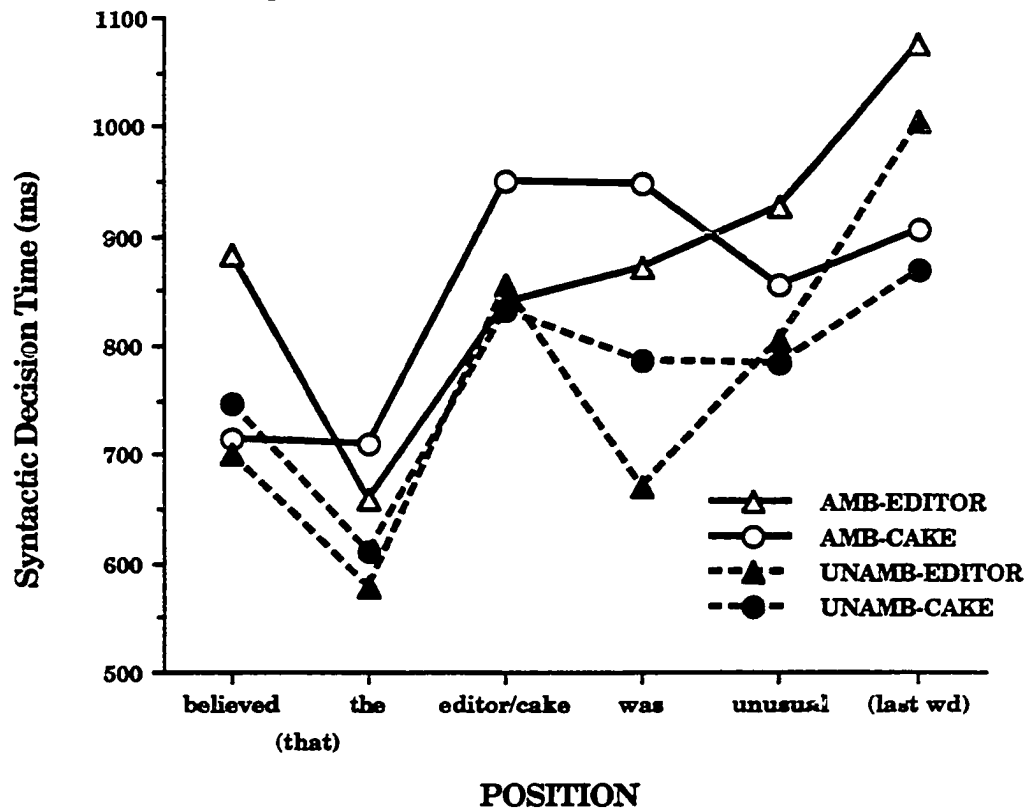
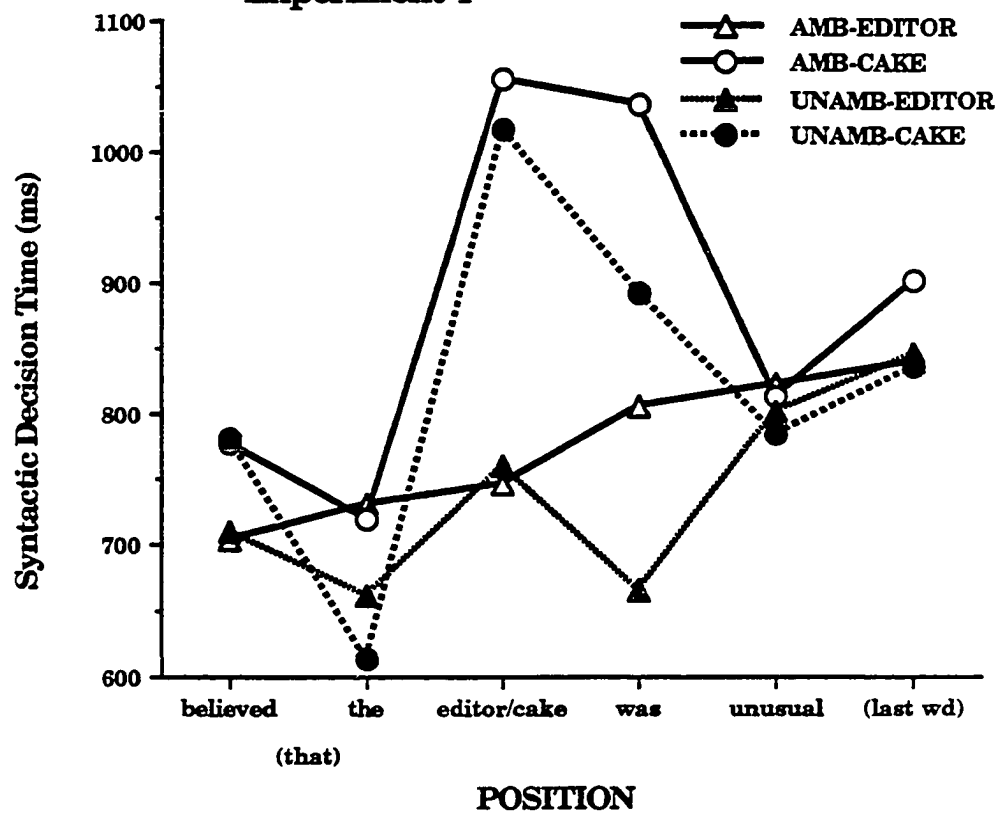


Figure 18: Clausal Biased Verbs from Experiment 4



each category. There was no statistically significant difference among even the most biased verbs.

Holmes, Stowe, and Cupples (in press) did a similar analysis on their materials and found that neither plausibility of the noun as a direct object nor structural ambiguity had any effect on the parsing of ambiguous complements preceded by clausal-biased verbs. Syntactic decision time was consistent across four sentence positions (determiner, noun, auxiliary/disambiguating word, and the following word). In the transitive-bias materials, no effect for noun plausibility was obtained in the reading time measures, although there was an effect of ambiguity at the auxiliary. In other words, they obtained a garden path effect for only the transitive-biased verb group. This apparent difference in parsing strategy was not subjected to a statistical test. Consistent with the results of the bias analysis of experiment 4 above, plausibility of the noun did not interact with ambiguity in their syntactic decision time data for either bias group. However, they did obtain differences between the two bias groups in their error analysis. The number of "ungrammatical" judgments occurring at the disambiguating word differed for the sentences containing plausible and implausible nouns in the two bias contexts. For clausal-biased verbs, nouns in the ambiguous region which were plausible as direct objects caused a very slight increase in the frequency of errors at the disambiguating word relative to sentences with nouns which were implausible as direct objects. In the

transitive-biased verbs, the frequency of errors at the disambiguating word was dramatically higher after a noun which was plausible as a direct object. Holmes et al. interpreted the results of their error analysis to mean that noun plausibility is used as a cue to the parser only after transitive-biased verbs. In my experiment, error rates were too low at all positions to draw such a conclusion.

Overall, parsing strategy for direct object/complement clause ambiguities was not strongly affected by the structural preferences of the verb. Small differences were occasionally apparent, sometimes reversible, and never statistically significant. This result, like the others obtained, supports parser modularity.

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CHAPTER 3

Summary of Experiments and General Discussion

It was six men of Indostan, to learning much inclined,
Who went to see the Elephant (though all of them were blind),
That each by observation might satisfy his mind.

The First approached the Elephant, and happening to fall
Against his broad and sturdy side, at once began to bawl:
"Bless me! but the Elephant is very like a wall!"

...

The Sixth no sooner had begun about the beast to grope,
Than, seizing on the swinging tail that fell within his scope,
"I see," quoth he, "the Elephant is very like a rope!"

And so these men of Indostan disputed loud and long,
Each in his own opinion exceeding stiff and strong,
Though each was partly in the right, and all were in the wrong!

(Saxe, 1852)

A summary of the results of all the experiments is presented in Table 5. The results concerning parsing strategy will be summarized first. The data from both the continuous syntactic and continuous lexical decision tasks show that the parser uses a serial strategy to process the main verb/participle ambiguities. Because the main verb structure is more frequently encountered in the language, the parser's preference for that structure over the participle structure may be strong enough that its initial assumption is, on the average, the most efficient path through sentences like these. This finding is in agreement with much of the garden path literature, although Gorrell (1987) obtained evidence of parallel processing

Table 5

Summary of Results

<u>EXPERIMENT</u>	<u>AMBIGUITY</u>	<u>PARSING STRATEGY</u>	<u>MODULAR ?</u>
1 (Syntactic)	MV/Part	Serial	Yes
1a (Lexical)	MV/Part	Serial	Yes
2 (Syntactic)	DO/Comp (short)	Serial or Delay	Yes
2a (Syntactic)	DO/Comp (short)	Serial or Delay	Yes
2b (Lexical)	DO/Comp (short)	? (uninformative)	Yes
3 (Syntactic)	DO/Comp (long)	Temporary Delay	Yes
3a (Lexical)	DO/Comp (long)	? serial (ns)	Yes
4 (Syntactic)	DO/Comp (plaus)	Delay	Yes
5 (Verb bias)	DO/Comp	---	Yes

of these kinds of materials. The disagreement may be due to differences in method. In the present study, changes in processing load were measured, whereas Gorrell used a secondary task to determine availability of alternate interpretations. Gorrell's results will be discussed further below.

The direct object/complement clause ambiguities seemed to follow the pattern predicted by the delay or temporary delay model. Intuitively, preferences for the direct object structure over the complement clause structure are caused by the probability differential in the language. The difference in frequency of the two structures are not as great as in the main verb/participle ambiguities described above, so a delay for more information may be the more efficient strategy. The mean decision times for ambiguous versions were consistently higher than their unambiguous control sentences during the ambiguous regions, and the processing load appeared to increase for the first three words of the ambiguity relative to the control sentence. Consistent with Slutsky's results, over long ambiguous regions, processing load returned to control levels until the disambiguating word, where it increased again. However, the magnitudes of the obtained differences were small across the ambiguous region. These nonsignificant but replicable effects support the temporary delay model, but not with the strength of statistically significant results. When significant differences were found, they occurred only at the disambiguating words, consistent with the serial model. Error analyses also supported the serial

model, with the highest frequencies at the disambiguating words in the nonpreferred versions. Although the slight increase in processing load may reflect that subjects are actually delaying their structural analysis for a few words, the lack of statistical support for this hypothesis disallows a stronger statement about the generality of the delay strategy.

Consistent with the results of Holmes, Stowe, and Cupples (in press), it did appear that a garden path effect at the disambiguating word was stronger with transitive-biased verbs (figure 13) than with clausal-biased verbs (figure 14), at least in one experiment. However, when the effects of structural preferences of individual verbs on parsing strategy were subjected to statistical testing, none of the apparent differences approached statistical significance. Previous studies in this area have not reported results of significance tests for the interaction of verb-bias and parsing strategy. But if lexical biases exist, they may do more than influence which structure a serial parser will compute first. Lexical preferences may bias the parser toward one or another strategy. When a transitive-biased verb is encountered, the parser may be more likely to operate serially, first computing only the transitive structure, since all early indicators suggest that a direct object is likely. A clausal-biased verb might cue the parser to use a parallel strategy, to prepare for either structure. Experiment 2a provided evidence of between-subject differences in structural preference. Variances in decision time at the disambiguating word were significantly

higher in the ambiguous complement clause resolutions than at the corresponding word in the clausal control sentences. This indicates that only some of the subjects were garden pathed. There was no significant difference in variances between ambiguous and unambiguous versions at that position for the transitive resolution.

The strongest and most consistent finding of the present experiments is that all the data support parser modularity. The manipulations included pragmatic bias of the material preceding the ambiguity, animacy of the noun in the ambiguous region, and plausibility of the noun as a direct object of the verb. None of these had any effect on structural preference or parsing strategy. Although there was an effect for plausibility of the noun in Experiment 4, the increased decision time occurred at the noun itself, in both ambiguous and unambiguous contexts. Its lack of interaction with ambiguity shows that plausibility did not have any syntactic effect. The difference was attributed to a lack of priming of the implausible noun relative to the plausible one. Although the constraints of this experiment were such that the word frequencies were not effectively matched, the implausible nouns actually had a higher average frequency than the nouns which were plausible as direct objects, ($t(17) = 2.2, p < .05$). The data clearly support the separation of semantic influences from syntactic language processing.

It has become clear that there is evidence from different sources for

each of the models described. Like the blind men and the elephant, each researcher uses a method which tells a specific truth about the way the parser can operate under a given set of constraints. No set of laboratory conditions has yet approximated natural language processing as we actually do it in our daily lives. Differences in tasks and materials inhibit effective generalization of results to other experimental situations, and to language understanding "in the wild."

In fact, the parser's strategy may be mutable rather than fixed. It appears that several processing modes are available to the parser, and we are beginning to see the relevant contextual events which contribute to the parser's selection of a mode of operation.

When processing is easy, the parser seems to be capable of carrying more than one syntactic structure at a time. Gorrell's evidence of the presence of alternative interpretations prior to disambiguation demonstrates this. His finding that a lexical decision on a syntactically nonpreferred target takes less time than a lexical decision on an ungrammatical target indicates that the nonpreferred structure is present during the ambiguous region to syntactically prime the target. However, when he substituted a syntactic decision task at the same position using the same materials, he found no evidence that the nonpreferred structure was being computed. He interpreted the results of the two experiments together to support parallel processing because the lexical decision task showed that the

nonpreferred structure was computed, and the syntactic decision task showed that the preferred one was computed, so together they show that both are computed. But it is possible, since syntactic decisions are more difficult than lexical decisions, that during the syntactic decision task, only the preferred structure was computed.

Gorrell's syntactic priming results are strong evidence that the parser is capable of parallel processing. Since the parser appears to be adaptable, it may normally do one kind of processing but can be pushed into another mode by the presence of these task-related measuring devices.

The results of my syntactic decision experiments were more supportive of a serial or delay model than a parallel one. The continuous syntactic decision task is a very difficult one, involving both mental and physical activity. Subjects press a key to receive each word, and make a grammaticality judgment at every word in the sentence or fragment. Since the task continuously requires so much of the subject's cognitive resources, it is not surprising that many subjects have insufficient remaining capacity for computation of additional structures.

The results of the continuous lexical decision task did not strongly support those obtained with the continuous syntactic decision task. The continuous syntactic decision task was more sensitive to on-line parsing decisions than the continuous lexical decision task. It appeared that syntactic processing in the lexical decision task may have lagged several

words behind presentation of stimulus items. Instead, the lexical decision task was more sensitive to lexical differences. This overall insensitivity and delayed response to syntactic events in the lexical decision task is apparent in figure 4, especially in contrast to the results of the syntactic decisions on the same materials shown in figure 3. Figure 4 shows a small difference in lexical decision time between the participle ambiguous and control versions at the disambiguating word. However, there is a much more profound difference between the two different resolutions (and therefore two different lexical items), at that position, regardless of whether an ambiguity was present. At the last word, differences representing possibly syntactic effects reappear. The continuous lexical decision task was even less successful with the more subtle transitive/complement ambiguities than with the main verb/participle ambiguities described above.

Since the syntactic decision task yielded more meaningful results than the lexical decision task, the validity of syntactic decision data, regardless of their relatively long durations, should be reaffirmed. The continuous syntactic decision task is not intended to give a meaningful absolute time measurement for parsing activities. The task is demanding of cognitive resources, and keeps the subject busy using a relatively constant amount of time per word. With the cognitive resources that remain, the subject is reading and understanding the sentence, admittedly

at a slowed down pace. It is the differences in decision times that reflect changes in processing difficulty. The absolute magnitudes of the times are less important, and should not be interpreted to indicate how long syntactic parsing normally takes. Although a secondary task completely unrelated to parsing, (such as finding the square root of some set of numbers after each word) would theoretically be adequate, the problem is ensuring that the subject is attending to the words in the sentence. Thus the decision must in some way be based on the stimulus item. These differences are easiest to see directly from the absolute response times, but I have included graphs of the calculated differences between adjacent points in figures 19, 20, 21, and 22.

Figure 19 shows the differences between syntactic decision times from experiment 1, which used the main verb/participle ambiguities. This interaction was significant, $F(4,88) = 3.98$, $p < .01$. Values above zero indicate that the second word of each pair had a longer decision time (that the original line went up) and values below zero show that the second word had a shorter decision time. When a difference is near zero, then the two decision times in the original analysis were about equal. Position 3 indicates the difference between the last word of the ambiguous region and the disambiguating word itself. The high value of the ambiguous participle ending at position 3 is consistent with the large increase in decision time apparent at position 4 in figure 3 (the original analysis). The large

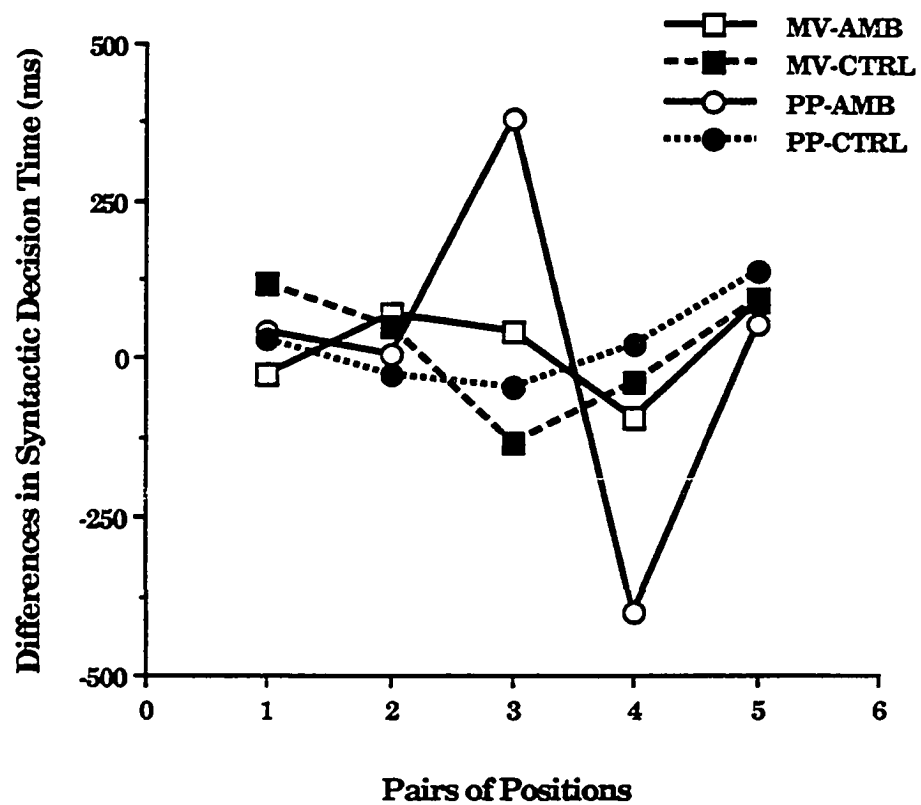
Figure 19: Slopes Analysis for Experiment 1

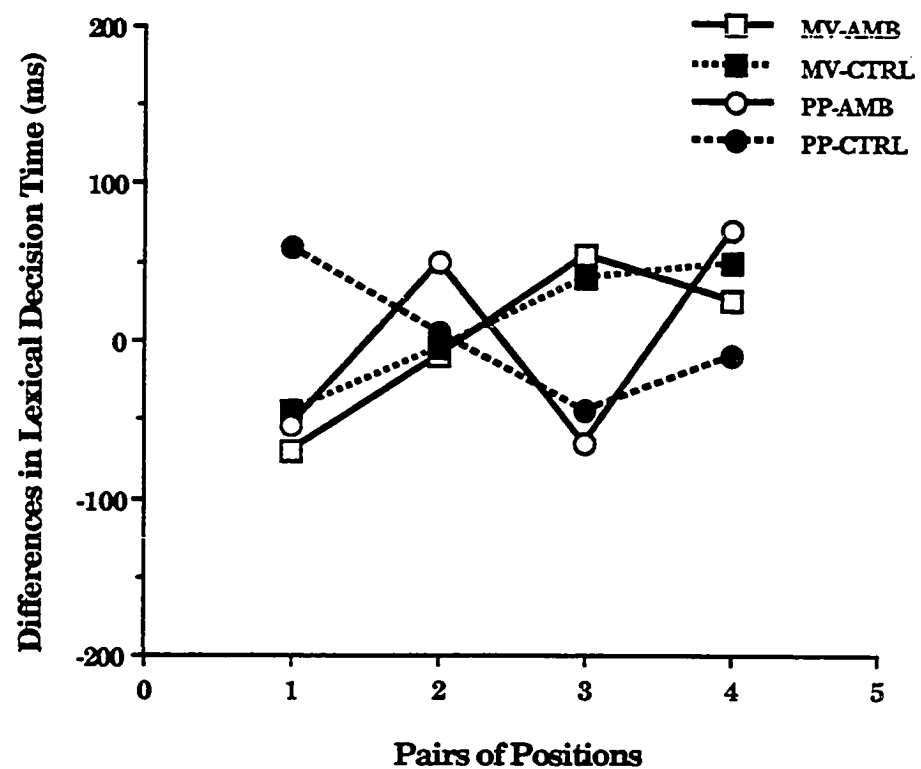
Figure 20: Slopes Analysis for Experiment 1a

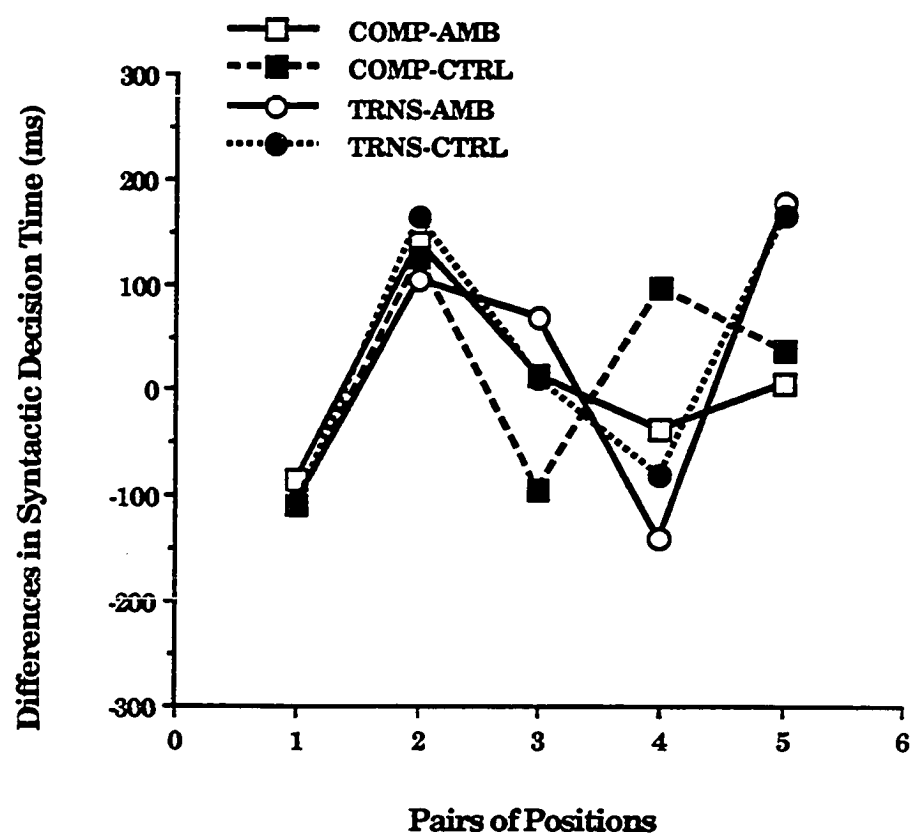
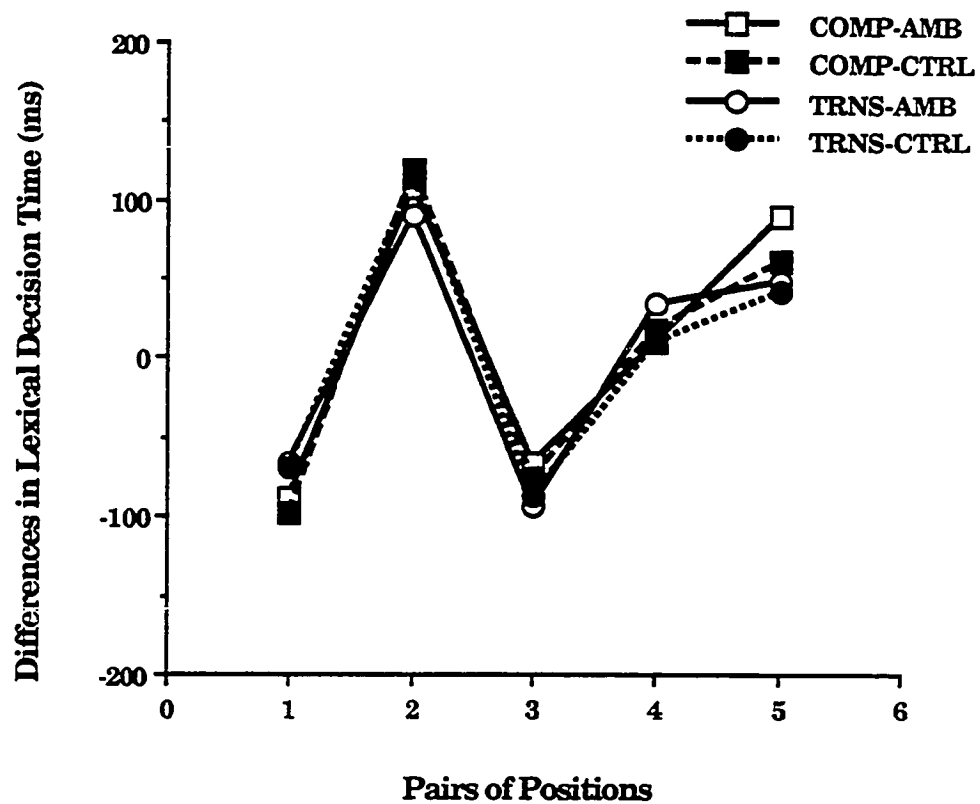
Figure 21: Slopes Analysis for Experiment 2a

Figure 22: Slopes Analysis for Experiment 2b

negative value at position 4 in figure 19 indicates that after disambiguation, syntactic decision time decreased. The other three lines in figure 19 do not deviate much from zero, showing that decision times were relatively constant across the sentences. Figure 20 shows the differences in lexical decision times for the main verb/participle ambiguities. This interaction also was significant, $F(4,124) = 8.86$, $p < .0001$. However, no meaningful pattern is evident.

For the direct object/complement clause ambiguities, the results of experiment 2a and 2b were also subjected to an analysis of the differences in decision times between adjacent words. Neither interaction was statistically significant. Figure 21 shows the analysis of the syntactic decision task, originally depicted in figure 6. All sentence versions show a decrease in syntactic decision time from the verb to the first word of the ambiguous region (position 1), and an increase at the second word of the ambiguous region. At the point of disambiguation, the ambiguous complement and the transitive control sentences stay about the same (differences near zero), the ambiguous transitive decision time increases and the complement control shows a decrease in decision time. At the next position, all versions indicate an decrease in decision time, except the complement control sentence which shows an increase. The lack of decrease in the ambiguous versions at the disambiguating word was used earlier as evidence of delayed processing. Figure 22 shows the

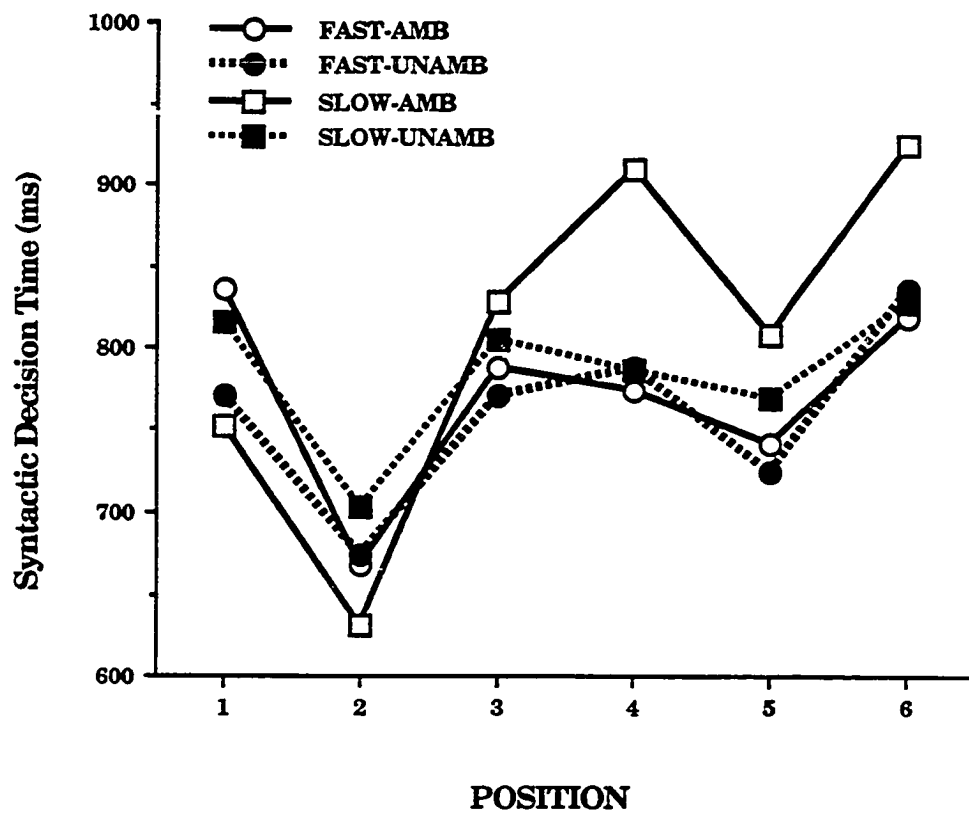
nonsignificant differences in lexical decision time between sentence resolutions corresponding to the ones in figure 7. All structures appear to be following a similar pattern. Although the original versions of the figures are easier to interpret, the advantage to the graphs of the decision time differences is that the relative changes between points are stressed rather than the absolute magnitude of the numbers.

If the parser is more flexible than has been supposed, its choice of strategy may be easily affected by many variables. Clearly, differences both in method and materials affect the parser's strategy. But laboratories studying parsing differ in more subtle ways as well. We use different subjects, with varying levels of reading fluency. There are small differences in presentation of stimuli, even when similar tasks are used. Filler or distractor materials may have some unknown effect, by themselves or in interaction with others of these variables. Robust phenomena are not appreciably diminished or altered by small variations in conditions, but the parser appears to be extremely sensitive to these small variations.

Macdonald (1989) has shown that fluent readers tend to do more parallel processing, and that less fluent readers process sentences using a serial strategy. This finding is consistent with the idea discussed above that the parser operates in a serial manner with difficult materials and in a parallel manner when the task is easier. Townsend, Carrithers and Bever

(1987) have shown that younger and poorer readers are less attuned to the presence of embedded clauses than adult fluent readers. Variability in my own timed data was large, possibly due to large disparities in reading fluency among subjects. We might speculate that very poor readers tend to concentrate on individual words before relating them to the sentence in progress. The length of time devoted to each word, then, is not necessarily related to parsing. Inclusion of these data has a more profound effect on the results than merely increasing mean reaction times. Differences in response time due to syntactic events may be obscured.

To test for the effects of reading fluency after the data were already collected, I sorted subjects on the basis of their average decision times and selected only the fastest ten and slowest ten subjects, deleting the data of the remaining subjects. When the fastest ten subjects were compared to the slowest ten subjects, some differences in processing strategy were found. In the direct object/complement clause ambiguities (experiment 2a), the interaction between reading speed, ambiguity and word position (shown in figure 23) was significant: $F(5,90) = 2.36, p < .05$. The increased decision time at the disambiguating word is present for only the slow readers. For fast readers, the ambiguous sentences are processed in the same way as the control sentences. This suggests differences in processing strategy among readers, but does not show whether the two different structural resolutions are handled differently by subjects who differ in reading fluency. The

Figure 23: Reading Speed and Ambiguity from Experiment 1

statistically nonsignificant differences depicting this relationship are shown in figures 24 and 25. Figure 24 shows that the slower readers apparently delayed processing. Both versions of the ambiguity show increasing loads across the ambiguous region relative to their controls. In both versions, the load is highest at the point of disambiguation. Figure 25 shows that faster readers do not show reliable differences between the ambiguous and unambiguous sentences for either resolution.

A separation of readers on the basis of fluency for experiment 4 showed significant differences: $F(5,90) = 3.23, p < .01$. Figure 26 shows that only the slower readers were stopped short at the implausible noun. Future experimenters should be alert to the effects of reading fluency, and consider pretests of reading fluency for subjects, and some general criteria for categories of fluency. Faster readers could be forced to slow down, either by insertion of a delay between words (Chodorow, personal communication), or by the use of partially degraded input (Fodor, personal communication). This would provide information about whether slower readers parse differently simply because of the extra time. If fluent but artificially slowed down readers show the same kinds of patterns as slower less fluent readers, then probably something other than natural parsing processes are being measured.

Slutsky (1989) used the continuous syntactic decision task, the difficulty of which I have held responsible for my apparently serial

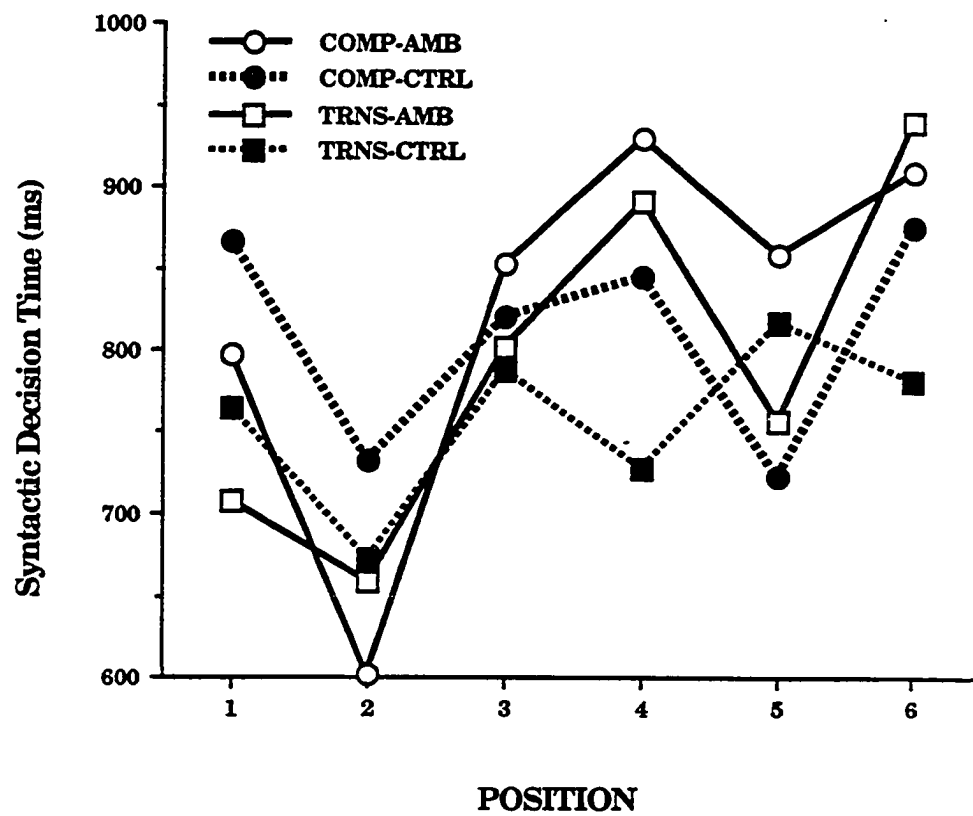
Figure 24: Slower readers from Experiment 2a

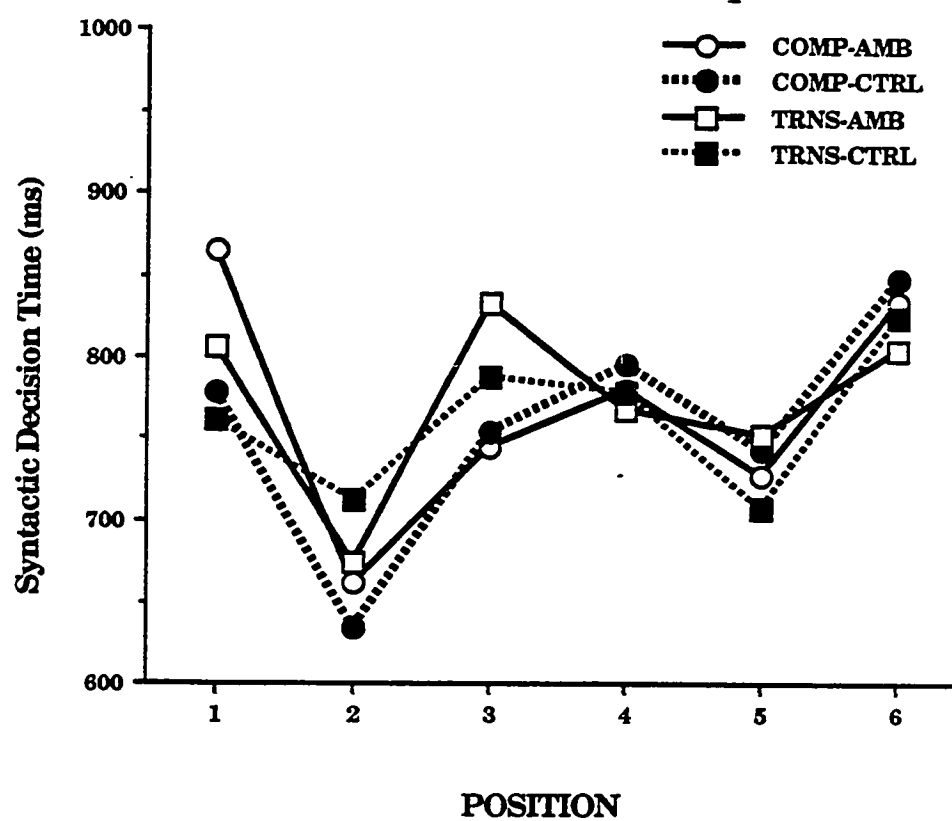
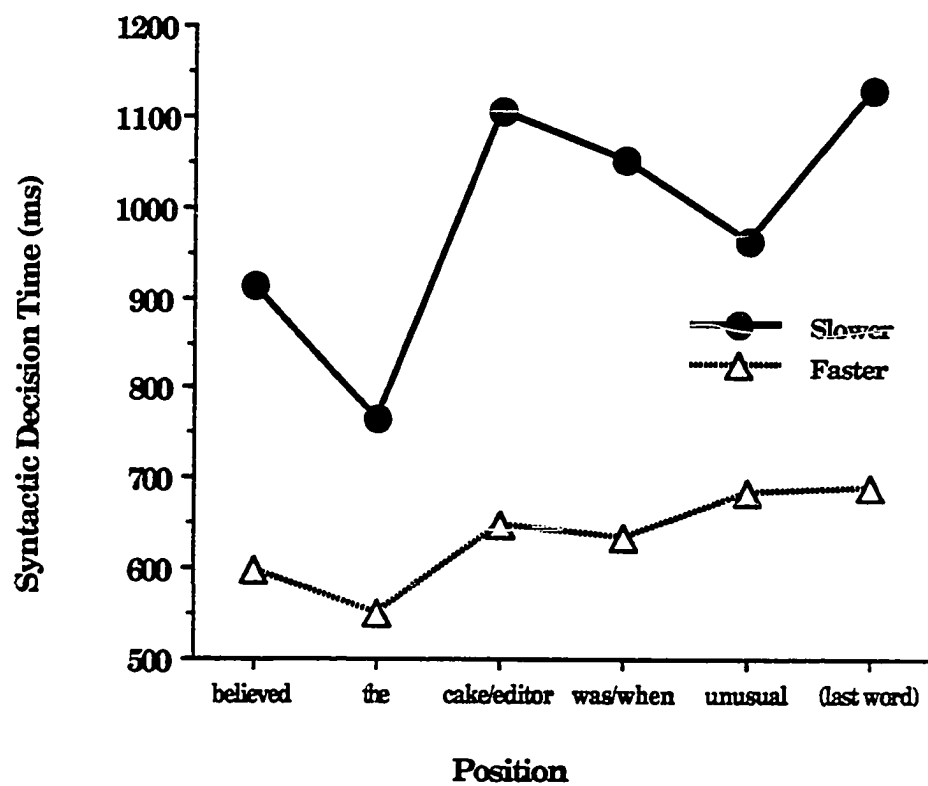
Figure 25: Faster readers from Experiment 2a

Figure 26: Reading Speed from Experiment 4

findings, and obtained results which were consistent with temporary parallel or delay models. It is unlikely that the subjects we used were very different, since we were working in the same laboratory. One difference between our techniques was our choice of filler materials. In my experiment 2, many of the filler items were identical to Slutsky's. The results of that one experiment were quite similar to his. The filler items we shared contained a relatively large cohort of sentences with embedded clauses. This bias may have created an expectation in the subjects that increased the likelihood that nonpreferred clausal structures would be computed. When in subsequent experiments, distractor materials did not contain this particular bias, the results appeared to conform to the serial model. All filler items are listed in the appendix.

Stowe and Cupples (1989) demonstrated that the manner in which stimuli are presented has a profound effect on the results obtained. They monitored reading times on materials containing main verb/participle ambiguities presented serially and centrally on a CRT screen, each word replacing the previous one (central display); then presented the same materials from left to right across the screen, again showing only one word at a time (sequential display). In a third condition (accumulating display), the same materials were presented from left to right across the screen, and each word remained on the screen until the entire sentence was presented. The sequential and cumulative display appeared to allow the animacy of

the noun in the ambiguous region to affect the selection of a computed structure (no statistical evidence for the interaction of animacy and ambiguity was reported), eliminating the garden path effect with the inanimate noun. Animacy did not affect parsing when the central display was used (relative clauses caused garden paths equally with both animate and inanimate objects). Because reading from the central display is more demanding of cognitive resources, the authors suggest that an earlier structural selection is required. This is not inconsistent with the idea that reading the sequential and accumulating displays is easier, and therefore more conducive to parallel processing, than reading from the central display, which appears to encourage serial processing. Also, the former presentation methods more closely approximate natural reading.

Task difficulty does not account for all findings of nonparallel processing however. The idea that all natural processing is parallel and the parser only does serial processing when pushed by unnatural task constraints is not supported by the results of eye movement studies. This task monitors reading in a manner which is closer to natural reading than any of the other techniques currently used, and findings are consistently serial.

Since each study reported in the literature differs on so many seemingly irrelevant variables, it is difficult to isolate the importance of any particular one. Some of these variables are of only methodological

interest, and others are of truly theoretical interest. For the methodologically interesting variables, such as task, materials, filler items, and stimulus presentation style, a valuable next step would be to sequentially vary each these factors one at a time, keeping all the others constant. Psycholinguistically interesting variables are ones which reveal how the parser actually functions.

Further research into the parser's apparent flexibility should include some developmental work. Early readers should be less capable of parallel processing than skilled ones. Aged populations may also lose parallel processing ability as other cognitive functions deteriorate. To measure the loss of parallel processing, a task which is most sensitive to its presence should be used. Gorrell's syntactic priming paradigm would be appropriate. Subjects should be more likely to do serial processing in their second language than in their native one. It would be interesting to test balanced bilingual subjects and note the extent of parallel processing present in each language. Another psycholinguistically interesting variable which should affect the parser's strategy is word frequency. Since high frequency words are easier to process, a parallel strategy would probably be used. With more difficult low frequency words, a serial strategy is more probable.

Appendix

Experimental Materials**Experiment 1**

The patient shaved in bed but got up to brush his teeth
The man shaved in bed but got up to brush his teeth
The patient had shaved in bed but got up to brush his teeth
The man had shaved in bed but got up to brush his teeth
The patient shaved in bed was very grateful
The man shaved in bed was very grateful
The patient they shaved in bed was very grateful
The man they shaved in bed was very grateful

The child dressed for the school play but didn't get to perform
The woman dressed for the school play but didn't get to perform
The child had dressed for the school play but didn't get to perform
The woman had dressed for the school play but didn't get to perform
The child dressed for the school play was a good actress
The woman dressed for the school play was a good actress
The child they dressed for the school play was a good actress
The woman they dressed for the school play was a good actress

The chickens prepared for their dinner but it never arrived
The chefs prepared for the dinner but it never arrived
The chickens had prepared for their dinner but it never arrived
The chefs had prepared for the dinner but it never arrived
The chickens prepared for the dinner were served promptly
The chefs prepared for the dinner were served promptly
The chickens they prepared for the dinner were served promptly
The chefs they prepared for the dinner were served promptly

The locksmith asked for the copied key but did not receive it yet
The new tenant asked for the copied key but did not receive it yet
The locksmith had asked for the copied key but did not receive it yet
The new tenant had asked for the copied key but did not receive it yet
The locksmith asked for the copied key handed it to the landlord
The new tenant asked for the copied key handed it to the landlord
The locksmith they asked for the copied key handed it to the landlord
The new tenant they asked for the copied key handed it to the landlord

The package dropped from the plane but did not reach its target
The soldier dropped from the plane but did not reach his target
The package had dropped from the plane but did not reach its target
The soldier had dropped from the plane but did not reach his target
The package dropped from the plane contained valuable papers
The soldier dropped from the plane carried valuable papers
The package dropped from the plane contained valuable papers
The soldier dropped from the plane carried valuable papers

The infant rocked to sleep but woke when the train abruptly stopped
The depressed man rocked to sleep but woke when the train abruptly stopped
The infant had rocked to sleep but woke when the train abruptly stopped
The depressed man had rocked to sleep but woke when the train abruptly stopped
The infant rocked to sleep awoke cheerfully seven hours later
The depressed man rocked to sleep awoke cheerfully seven hours later
The infant they rocked to sleep awoke cheerfully seven hours later
The depressed man they rocked to sleep awoke cheerfully seven hours later

The police told about the riots but nobody believed them
The eyewitness told about the riots but nobody believed him
The police had told about the riots but nobody believed them
The eyewitness had told about the riots but nobody believed him
The police told about the riots voted to take the risk
The eyewitness told about the riots voted to take the risk
The police they told about the riots voted to take the risk
The eyewitness they told about the riots voted to take the risk

The condemned prisoners marched along the road but collapsed on the swampy field
The musicians marched along the road but collapsed on the swampy field
The condemned prisoners had marched along the road but collapsed on the swampy field
The musicians had marched along the road but collapsed on the swampy field
The condemned prisoners marched along the road made the sheriff very nervous
The musicians marched along the road made the sheriff very nervous
The condemned prisoners they marched along the road made the sheriff very nervous
The musicians they marched along the road made the sheriff very nervous

The small group lectured about drunk driving but failed to follow their own rules
The lawyer lectured about drunk driving but failed to follow his own rules
The small group had lectured about drunk driving but failed to follow their own rules
The lawyer had lectured about drunk driving but failed to follow his own rules
The small group lectured about drunk driving listened to every word
The lawyer lectured about drunk driving listened to every word
The small group they lectured about drunk driving listened to every word
The lawyer they lectured about drunk driving listened to every word

The expert consulted in the morning but relaxed in the afternoon
The director consulted in the morning but relaxed in the afternoon
The expert had consulted in the morning but relaxed in the afternoon
The director had consulted in the morning but relaxed in the afternoon
The expert consulted in the morning was given all the facts
The director consulted in the morning was given all the facts
The expert they consulted in the morning was given all the facts
The director they consulted in the morning was given all the facts

The graduate students taught by the new method but secretly preferred the old one
The adjunct instructors taught by the new method but secretly preferred the old one
The graduate students had taught by the new method but secretly preferred the old one
The adjunct instructors had taught by the new method but secretly preferred the old one

The graduate students taught by the new method knew the material quite well
The adjunct instructors taught by the new method knew the material quite well
The graduate students they taught by the new method knew the material quite well
The adjunct instructors they taught by the new method knew the material quite well

The soldier killed in the line of duty but never failed to pray for the souls of his victims
The assassin killed in the line of duty but never failed to pray for the souls of his victims
The soldier had killed in the line of duty but never failed to pray for the souls of his victims
The assassin had killed in the line of duty but never failed to pray for the souls of his victims
The soldier killed in the line of duty received a posthumous medal
The assassin killed in the line of duty received a posthumous medal
The soldier they killed in the line of duty received a posthumous medal
The assassin they killed in the line of duty received a posthumous medal

The people warned about the layoffs but the community paid no attention
The officials warned about the layoffs but the community paid no attention
The people had warned about the layoffs but the community paid no attention
The officials had warned about the layoffs but the community paid no attention
The people warned about the layoffs wanted to stage a protest
The officials warned about the layoffs wanted to stage a protest
The people they warned about the layoffs wanted to stage a protest
The officials they warned about the layoffs wanted to stage a protest

The woman called at night but she was still unable to catch him at home
The nosy reporter called at night but she was still unable to catch him at home
The woman had called at night but she was still unable to catch him at home
The nosy reporter had called at night but she was still unable to catch him at home
The woman called at night was angry at being disturbed
The nosy reporter called at night was angry at being disturbed
The woman they called at night was angry at being disturbed
The nosy reporter they called at night was angry at being disturbed

The elderly lady pushed into the crowd but could not get through
The bodyguard pushed into the crowd but could not get through
The elderly lady had pushed into the crowd but could not get through
The bodyguard had pushed into the crowd but could not get through
The elderly lady pushed into the crowd shouted as she was being trampled
The bodyguard pushed into the crowd shouted as he was being trampled
The elderly lady they pushed into the crowd shouted as she was being trampled
The bodyguard they pushed into the crowd shouted as he was being trampled

The customer charged for the repairs but he was unable to fix the owner's car
The manager charged for the repairs but he was unable to fix the owner's car
The customer had charged for the repairs but he was unable to fix the owner's car
The manager had charged for the repairs but he was unable to fix the owner's car
The customer charged for the repairs demanded a full refund
The manager charged for the repairs demanded a full refund
The customer they charged for the repairs demanded a full refund
The manager they charged for the repairs demanded a full refund

Experiment 2 (additions to NP's for Experiment 3 in parentheses below each set)

The reporter believed that the editor was amusing
The reporter believed that the story was amusing
The reporter believed the editor was amusing
The reporter believed the story was amusing
The reporter believed the editor but doublechecked the facts anyway
The reporter believed the story but doublechecked the facts anyway
The reporter praised the editor but doublechecked the facts anyway
The reporter praised the story but doublechecked the facts anyway
(from the Kansas City Herald)

The mother expected that the attorney would arrive at any moment
The mother expected that the newspaper would arrive at any moment
The mother expected the attorney would arrive at any moment
The mother expected the newspaper would arrive at any moment
The mother expected the attorney but left the house anyway
The mother expected the newspaper but left the house anyway
The mother called the attorney but left the house anyway
The mother called the newspaper but left the house anyway
(from beyond the next town)

The delivery man noticed that the youngster was outside
The delivery man noticed that the garbage was outside
The delivery man noticed the youngster was outside
The delivery man noticed the garbage was outside
The delivery man noticed the youngster when he went out to start the car
The delivery man noticed the garbage when he went out to start the car
The delivery man struck the youngster when he went out to start the car
The delivery man struck the garbage when he went out to start the car
(from the local pizza store)

The businessman forgot that the driver would be waiting at the airport
The businessman forgot that the taxi would be waiting at the airport
The businessman forgot the driver would be waiting at the airport
The businessman forgot the taxi would be waiting at the airport
The businessman forgot the driver when he rushed onto the bus
The businessman forgot the taxi when he rushed onto the bus
The businessman blocked the driver when he rushed onto the bus
The businessman blocked the taxi when he rushed onto the bus
(from the Caribbean limousine service)

The rescuers discovered that the survivor was on the north slope
The rescuers discovered that the wreckage was on the north slope
The rescuers discovered the survivor was on the north slope
The rescuers discovered the wreckage was on the north slope
The rescuers discovered the survivor when they made a last attempt
The rescuers discovered the wreckage when they made a last attempt
The rescuers located the survivor when they made a last attempt

The rescuers located the wreckage when they made a last attempt
(of last year's air disaster)

The pirate demanded that the captive be thrown overboard
The pirate demanded that the contraband be thrown overboard
The pirate demanded the captive be thrown overboard
The pirate demanded the contraband be thrown overboard
The pirate demanded the captive when he boarded the injured vessel
The pirate demanded the contraband when he boarded the injured vessel
The pirate dropped the captive when he boarded the injured vessel
The pirate dropped the contraband when he boarded the injured vessel
(on the plundered cargo ship)

The private investigator noticed that the clergyman remained in the hotel lobby
The private investigator noticed that the luggage remained in the hotel lobby
The private investigator noticed the clergyman remained in the hotel lobby
The private investigator noticed the luggage remained in the hotel lobby
The private investigator noticed the clergyman when he arrived in the hotel lobby
The private investigator noticed the luggage when he arrived in the hotel lobby
The private investigator studied the clergyman when he arrived in the hotel lobby
The private investigator studied the luggage when he arrived in the hotel lobby
(from the recent religious expedition)

The detective revealed that the burglars were now out of the country
The detective revealed that the jewels were now out of the country
The detective revealed the burglars were now out of the country
The detective revealed the jewels were now out of the country
The detective revealed the burglars when he threw back the curtain
The detective revealed the jewels when he threw back the curtain
The detective spotted the burglars when he threw back the curtain
The detective spotted the jewels when he threw back the curtain
(from the famous museum heist)

The witness remembered that the woman stayed by the pool most of the afternoon
The witness remembered that the party stayed by the pool most of the afternoon
The witness remembered the woman stayed by the pool most of the afternoon
The witness remembered the party stayed by the pool most of the afternoon
The witness remembered the woman but tried to change the subject
The witness remembered the party but tried to change the subject
The witness visited the woman but tried to change the subject
The witness visited the party but tried to change the subject
(from/for the new convention center)

The warden doubted that the prisoner had been completely honest
The warden doubted that the story had been completely true
The warden doubted the prisoner had been completely honest
The warden doubted the story had been completely true
The warden doubted the prisoner but agreed to a new hearing
The warden doubted the story but agreed to a new hearing
The warden fought the prisoner but agreed to a new hearing
The warden fought the story but agreed to a new hearing

(of the powerful street gang)

The tour guide found that the anthropologists were still in the room
 The tour guide found that the groceries were still in the room
 The tour guide found the anthropologists were still in the room
 The tour guide found the groceries were still in the room
 The tour guide found the anthropologists when he arrived
 The tour guide found the groceries when he arrived
 The tour guide left the anthropologists when they arrived
 The tour guide left the groceries when they arrived

(from/for the cultural affairs group)

The committee reported that the teachers were new to the school
 The committee reported that the books were new to the school
 The committee reported the teachers were new to the school
 The committee reported the books were new to the school
 The committee reported the teachers when it learned of their immoral behavior
 The committee reported the books when it learned of their immoral contents
 The committee removed the teachers when it learned of their immoral behavior
 The committee removed the books when it learned of their immoral contents

(with controversial and untested ideas)

The youngster imagined that her daddy had turned into a magic dragon
 The youngster imagined that her pillow had turned into a magic dragon
 The youngster imagined her daddy had turned into a magic dragon
 The youngster imagined her pillow had turned into a magic dragon
 The youngster imagined her daddy when she needed to feel safe
 The youngster imagined her pillow when she needed to feel safe
 The youngster touched her daddy when she needed to feel safe
 The youngster touched her pillow when she needed to feel safe

(the daddy/pillow on the special television program)

The gray-haired gentleman recalled that the dog was brown and spotted
 The gray-haired gentleman recalled that the desk was brown and spotted
 The gray-haired gentleman recalled the dog was brown and spotted
 The gray-haired gentleman recalled the desk was brown and spotted
 The gray-haired gentleman recalled the dog but could not find another like him
 The gray-haired gentleman recalled the desk but could not find another like it
 The gray-haired gentleman bought the dog but could not find another like him
 The gray-haired gentleman bought the desk but could not find another like it

(from the historic Louisiana mansion)

The judge requested that the lawyer remain in the courtroom
 The judge requested that the evidence remain in the courtroom
 The judge requested the lawyer remain in the courtroom
 The judge requested the evidence remain in the courtroom
 The judge requested the lawyer but was dissatisfied with his effect
 The judge requested the evidence but was dissatisfied with its effect
 The judge refused the lawyer but was dissatisfied with his effect
 The judge refused the evidence but was dissatisfied with its effect

(in the mercy killing case)

The inspector saw that the girls worked all day Saturday
The inspector saw that the machine worked all day Saturday
The inspector saw the girls worked all day Saturday
The inspector saw the machine worked all day Saturday
The inspector saw the girls when the factory doors opened
The inspector saw the machine when the factory doors opened
The inspector passed the girls when the factory doors opened
The inspector passed the machine when the factory doors opened
(from the clothing manufacturing company)

The physician judged that the patient was improving
The physician judged that the condition was improving
The physician judged the patient was improving
The physician judged the condition was improving
The physician judged the patient when she learned he had abused drugs
The physician judged the condition when she learned the patient had abused drugs
The physician discussed the patient when she learned he had abused drugs
The physician discussed the condition when she learned the patient had abused drugs
(with the very complex diagnosis)

The young poet heard that the singer was incredibly beautiful
The young poet heard that the music was incredibly beautiful
The young poet heard the singer was incredibly beautiful
The young poet heard the music was incredibly beautiful
The young poet heard the singer when he passed by the rehearsal hall
The young poet heard the music when he passed by the rehearsal hall
The young poet stopped the singer when he passed by the rehearsal hall
The young poet stopped the music when he passed by the rehearsal hall
(from the small Czechoslovakian village)

Experiment 4

The reporter believed that the editor was unusual
The reporter believed that the cake was unusual
The reporter believed the editor was unusual
The reporter believed the cake was unusual

The mother expected that the attorney would charge exorbitant fees
The mother expected that the university would charge exorbitant fees
The mother expected the attorney would charge exorbitant fees
The mother expected the university would charge exorbitant fees

The delivery man noticed that the youngster was not difficult to understand
The delivery man noticed that the idea was not difficult to understand
The delivery man noticed the youngster was not difficult to understand
The delivery man noticed the idea was not difficult to understand

The businessman forgot that the driver was dirty

The businessman forgot that the air was dirty
The businessman forgot the driver was dirty
The businessman forgot the air was dirty

The rescuers discovered that the survivor was calmer on the north slope
The rescuers discovered that the weather was calmer on the north slope
The rescuers discovered the survivor was calmer on the north slope
The rescuers discovered the weather was calmer on the north slope

The pirate demanded that the captive pay for the damages
The pirate demanded that the hospital pay for the damages
The pirate demanded the captive pay for the damages
The pirate demanded the hospital pay for the damages

The private investigator noticed that the clergyman was spattered with paint
The private investigator noticed that the wall was spattered with paint
The private investigator noticed the clergyman was spattered with paint
The private investigator noticed the wall was spattered with paint

The detective revealed that the burglar was sponsoring aid for the homeless
The detective revealed that the government was sponsoring aid for the homeless
The detective revealed the burglar was sponsoring aid for the homeless
The detective revealed the government was sponsoring aid for the homeless

The witness remembered that the woman was injured in the commotion
The witness remembered that his hand was injured in the commotion
The witness remembered the woman was injured in the commotion
The witness remembered his hand was injured in the commotion

The warden doubted that the prisoner had been completely honest
The warden doubted that the room had been completely cleaned
The warden doubted the prisoner had been completely honest
The warden doubted the room had been completely cleaned

The tour guide found that the anthropologists needed some assistance
The tour guide found that the morale needed some improvement
The tour guide found the anthropologists needed some assistance
The tour guide found the morale needed some improvement

The committee reported that the teachers were seriously behind the times
The committee reported that the sociology was seriously behind the times
The committee reported the teachers were seriously behind the times
The committee reported the sociology was seriously behind the times

The youngster imagined that her daddy had turned into a magic dragon
The youngster imagined that the thought had turned into a magic dragon
The youngster imagined her daddy had turned into a magic dragon
The youngster imagined the thought had turned into a magic dragon

The gray-haired gentleman recalled that the dog was perfect
The gray-haired gentleman recalled that the relationship was perfect

The gray-haired gentleman recalled the dog was perfect
 The gray-haired gentleman recalled the relationship was perfect

The judge requested that the lawyer remain outside the courtroom
 The judge requested that the hostility remain outside the courtroom
 The judge requested the lawyer remain outside the courtroom
 The judge requested the hostility remain outside the courtroom

The inspector saw that the girls had caused permanent structural damage
 The inspector saw that the noise had caused permanent structural damage
 The inspector saw the girls had caused permanent structural damage
 The inspector saw the noise had caused permanent structural damage

The physician judged that the patient was getting stronger
 The physician judged that the wind was getting stronger
 The physician judged the patient was getting stronger
 The physician judged the wind was getting stronger

The young poet heard that the singer was incredibly beautiful
 The young poet heard that the museum was incredibly beautiful
 The young poet heard the singer was incredibly beautiful
 The young poet heard the museum was incredibly beautiful

Filler Items

Experiment 1

The cats are wearing party clothes for the if
 For next season the team aims to
 The turkey dressed for Thanksgiving dinner was is
 Parking the car is so inconvenient when but
 For tax purposes the town records are book
 Those beer bottles are piling up in the doorway
 The soup that was boiled in the pot door
 For this quarter the company estimates are lower tall
 Please give me a hand with these packages
 In my car the window shields against then
 The man chosen the when
 After midnight these truck stops are more frequent
 Too many loud mouths us
 This month these bill amounts are more than I can afford
 The pencil sharpener is full pods
 Before battle all warrior faces are painted black
 The pumpkin selected for the neither
 The boat that was steered violations
 When it is hot a dog bites more viciously
 Please change the baby's today
 My new computer forget

By state law the bank exchanges are monitored
The dancers who were found dead were not in of
The oil poured on the went
In spring weather the tree flowers in does
Sometimes they assign too fortune
Every hour the radio broadcasts the world news report
When the show closes she will collect unemployment airplane
The material learned book
It's good that these church benefits raise of
It's not the heat cold
The magic markers are all dried plan
For our parties a restaurant supplies the appetizers
My battery was stolen again last night
The letters mailed at the post office were never school
The mayor feels that the homeless cause more can
The final exam taken pig
In an emergency those town reserves can be rationed
The stewardess bent over the of
Those are the same pants you me
The priest says the parish hopes the donation accept
The woman forgot her umbrella the day it he
In first grade the school reports are more promising for children
The holidays celebrated last cupcake
The review said that the movie passes will be honored
The laboratory animals used in for
In general all government protests are widely publicized
The cockroaches exterminated by for
Usually the carpenter measures more accurately we
Next month will be the for
In this magazine the automobile rates very highly
We are taught that the court fights for said
Her work is improving and may be belong
In town the neighborhood patrols are very dangerous
The electrician's favorite food be
Along this highway the road bends are slippery raining
The tickets distributed early were are
It is better if an airline schedules most flights early
The athlete trained early run
Silly images come to mind with of
At the race track a bookie bets more few
The rules created by the new government were strictly table
Often a club groups together similar people
Frankenstein walked in a slow awkward she
For this quarter the company estimates are have
When the young girl thought about in
On Wednesday those bus guides were more friendly to us
The only bad thing that happened yesterday was is
From here the prisoner escapes without caught
She had been aware that the of
That mean teacher always never
On white paper the pencil marks very easily

My recipe says that the beef roasts can defrosted
 Clean up your his
 She purchased new shoes at least once a week but he we
 The judge said the criminal looks guilty and dangerous
 With the commercial brand these pot handles are become
 If you would be more comfortable then dog
 They reported that the city permits are difficult to obtain
 The chemistry exam was easier than until
 Hats off to the of
 In the office the manager phones the to

Experiments 1a and 2b

The cats are wearing party clothes for the cughod
 For next season the team aims to soldid
 The turkey dressed for Thanksgiving dinner was nufry
 Parking the car is so inconvenient when floofed
 For tax purposes the town records are proikl
 Those beer bottles are piling up in the doorway
 The soup that was boiled in the pot lublot
 For this quarter the company estimates are lower hamloj
 Please give me a hand with these packages
 In my car the window shields against denisled
 The man chosen the solemden
 Too many loudmouths musple
 The pencil sharpener is full desuged
 The pumpkin selected for the ej
 The boat that was steered stex
 Please change the baby's lij
 My new computer krimble
 The dancers who were found dead were not in belmunt
 The oil poured on the nolly
 In spring weather the tree flowers in almund
 Sometimes they assign too wolp
 When the show closes she will collect unemployment smollow
 The material learned dagged
 It's good that these church benefits raise wosten
 It's not the heat yolsh
 The magic markers are all dried clasdel
 My battery was stolen again last fobolg
 The letters mailed at the post office were never vok
 The mayor feels that the homeless cause more footpid
 The final exam taken gik
 The stewardess bent over the elgept
 Those are the same pants you ag
 The priest says the parish hopes the donation pleaches
 The woman forgot her umbrella the day it plodos
 The holidays celebrated last wug
 The review said that the movie passes will gabner
 The laboratory animals used in mofused
 The cockroaches exterminated by swulled

Usually the carpenter measures more accurately dralsing
Next month will be the mersty
We are taught that the court fights for smickle
Her work is improving and may be eptult
The electrician's favorite food wolmith
Along this highway the road bends are slippery dasteg
The tickets distributed early were pelmunt
The athlete trained early floxed
Silly images come to mind with fep
At the race track a bookie bets more nuglin
The rules created by the new government were strictly culsodes
Frankenstein walked in a slow awkward lorp
For this quarter the company estimates are flirg
When the young girl thought about shofip
The only bad thing that happened yesterday was nampog
From here the prisoner escapes without crolp
She had been aware that the ommzy
That mean teacher always durnt
My recipe says that the beef roasts can frizod
Clean up your blim
She purchased new shoes at least once a week but he wroo
With the commercial brand these pot handles are tivley
If you would be more comfortable then stimp
The chemistry exam was easier than anblug
Hats off to the cherlts
In the office the manager phones the empcroz

Experiment 2

The resourceful teacher found that the children all and
Their slanderous remarks annoy could
The detective questioned our neighbor after the
The impending nuclear teach
The hero leaped to the without
The cow that the butcher warned us about was the know
Too few cups us
Those clues that the people decided very errors
He believed someone was spying on
The coach insisted that the new when
The swimmers trained hard for the race
Within of
When Sam's little daughter kicked the postman he threatened to sue
Many trees were injured pipe
Near the arena was standing might
The clamps that who
Before Fred discovered the combination to John's locker he was able to open it
The mechanic that however
An enjoyable his
The cashier that the customers considered honest became was
The respectful nuns that watched the baby at laughed
Just as the plane was spotted by the man with the telescope it fell from his hand

If all goes too while
Because the student's exam was misplaced by the instructor she had to take a makeup
As the cement was unloaded by the driver of the truck it flowed over the curb
The priest that if
Although the woman's drug was administered by the nurse she only gave half the usual amount
They sold the painting smile
Although the rewards were merely was
The man that when
The scouts that why
The frustrated musician moved the piano from the basement to the room sing
Weary of the long drive them
Because the owner of the restaurant prepared the food it was always crowded
Until the lawyers defended the client's lawsuit they did not pay
Since the woman's jewelry delighted the queen she decided to buy it
The newscaster that reported the information to about
Some people believe that their best the
The diligent lawyer found the policy to be much never
The oldfashioned barber that the hairdresser brought the liking
Although the guardian paid the boy's tuition he received another bill
The company that beside
When trees were planted were planted by the chief of the forest rangers they were all amazed
When misleading claims about the product were presented by the commercial it was taken off grocery shelves
Shortly after the new office was rented by the company's manager it went bankrupt
The careful waiter that carried the salad was extremely lettuce
When the coach's best players were suspended by the dean he could not win the game
The sheriff arrested the tell
The singer reported the song for with
After the father was hit by the boy's baseball he was angry
The only answer floor
Since the ballerina's toeshoe was broken by the understudy she was fired right away
Each sheep had been died
Little time has been door
The bitter cold forced people lose
All of run
The city worker met the district representative for seems
After Tim's grandparents gave the boy a treat he wanted one also
Before the repairman fixed the Smith's house they had to live with broken steps
Two men rode quickly stare
The manager escorted the visitor think
Even though the medicine in drugstores helps patients they don't carry enough of it
Finishing the race was all some and why
The school that end
When the policeman arrested the boy's mother he sent her to prison
It around
Even though Christopher was bumped by Tom's truck he did not stop
Whoever finds the course too table
When Nelly's boss was criticized by the woman she didn't believe it
The skilled jeweler made the bracelet with the asked

The chef cooked the roast on the include
When Fran was hugged by Mary's uncle she warmly returned his embrace
The best guitarist playing acoustic jazz is undoubtedly were
The dogs that is
The helpful caretaker carried the statue from the garden to the under
The proud dancer that showed the director his studio with under
The fearful soldiers guarded the office near the translate
The before
Before we tomorrow
After the patron's drink was served by the bartender he left a big tip

Experiment 2a

The cashier that the customer considered honest became was
The chef cooked the roast on the include
The swimmers trained hard for the race
Some people believe that their best the
The diligent lawyer found the policy to be much never
The oldfashioned barber that the hairdresser brought the liking
The resourceful teacher found that the children all and
The company that beside
The newscaster that reported the information to about
The best guitarist playing acoustic jazz is undoubtedly were
The man that when
Although the rewards were merely was
After midnight these truck stops are more frequent
The scouts that why
The frustrated musician moved the piano from the basement to the room sing
The dogs that is
Before the battle all warrior's faces are painted black
Two men rode quickly store
The skilled jeweler made the bracelet with the asked
By state law the bank exchanges are monitored
The careful waiter that carried the salad was extremely lettuce
All of run
Every hour the radio broadcasts the world news report
The bitter cold forces people lose
The city worker met the district representative for seems
For our parties a restaurant supplies the appetizers
The school that end
In an emergency those town reserves can be rationed
The manager escorted the visitor think
Finishing the race was all some why
Little time has been door
In first grade the school reports are more promising for children
Each sheep had been died
In general all government protests are widely publicized
The sheriff arrested the tell
Whoever finds the course too table
In this magazine the automobile rates very highly
The singer reported the song for with

The only answer floor
 In town the neighborhood patrols are very dangerous
 It around
 It is better if an airline schedules most flights early
 They sold the painting smile
 Often a club groups together similar people
 Weary of the long drive them
 The coach insisted that the new when
 On Wednesday those bus guides were more friendly to us
 Within of
 Before we tomorrow
 On white paper the pencil marks very easily
 The helpful caretaker carried the statue from the garden to the under
 The judge said the criminal looks guilty and dangerous
 Many trees were injured pipe
 He believed someone was spying on
 They reported that the city permits are difficult to obtain
 Those clues that the people decided very errors
 The detective questioned our neighbor after the
 Their slanderous comments annoy could
 This month these bill amounts are more than I can afford
 The impending nuclear teach
 When it is hot a dog bites more viciously
 The hero leaped to the without
 Too few cups us
 During a competition this horse show its ability
 The cow that the butcher warned us about was the know
 The clamps that who
 Before the race begins a clock times several test runs
 Near the arena was standing might
 Over the next few weeks the team aims are being
 The before
 The mechanic that however
 For tax purposes the town records all property sales
 The fearful soldiers guarded the office near the translate
 The respectful nuns that watched the baby at laughed
 An enjoyable his
 Next quarter the company estimates a rise in profits
 If all goes too while
 The priest that if
 The mayor believes that the homeless cause is a worthy
 The proud dancer that showed the director his studio with under

Experiments 3 and 3a

The resourceful teacher found that the children all and/cughod
 Their slanderous remarks annoy could/solsid
 The detective questioned our neighbor after the
 The impending nuclear teach/nufry
 The hero leaped to the without/floofed
 The cow that the butcher warned us about was the know/proikl

Too few cups us/lublot
 Those clues that the people decided very errors/hamloj
 He believed someone was spying on
 The coach insisted that the new when/denised
 Within of/solemden
 Many trees were injured pipe/musple
 Near the arena was standing might/desuged
 The clamps that who/ej
 The mechanic that however/stex
 An enjoyable his/lij
 The respectful nuns that watched the baby at laughed/krimble
 If all goes too while/belmup
 The priest that if/nolly
 They sold the painting smile/almunt
 Although the rewards were merely was/wolp
 The man that when/smollow
 Weary of the long drive them/daggled
 Some people believe that their best the/wosten
 The diligent lawyer found the policy to be much never/yolsh
 The oldfashioned barber that the hairdresser brought the liking/clasdel
 The company that beside/fobolg
 The sheriff arrested the tell/vok
 The singer reported the song for with/foopaid
 The only answer floor/gik
 Each sheep had been died/elgept
 Little time has been door/ag
 The bitter cold forced people lose/pleaches
 Two men rode quickly stare/plodos
 The manager escorted the visitor think/wug
 Finishing the race was all some why/gabner
 The school that end/mofused
 It around/swulled
 Whoever finds the course too table/dralsing
 The before/mersty
 The chef cooked the roast on the include/smickle
 The best guitarist playing acoustic jazz is undoubtedly were/eptult
 The dogs that is/wolmith
 The proud dancer that showed the director his studio with under/dasteg
 The fearful soldiers guarded the office near the translate/pelmunt
 Before we tomorrow/floxed
 All of run/fep
 The scouts that why/nuglin
 The frustrated musician moved the piano from the basement to the room sing/culsodes

Experiment 4

The resourceful teacher found that the children all and
 Their slanderous comments annoy could
 The detective questioned our neighbor after the
 The impending nuclear teach
 The hero leaped to the without

The cow that the butcher warned us about was the know
Too few cups us
Those clues that the people detected very errors
He believed someone was spying on
The coach insisted that the new when
The swimmers trained hard for the race
Within of
Many trees were injured pipe
Near the arena was standing might
The clamps that who
In our old house the closet was much larger
I couldn't get in because the opener was broken
The mechanic that however
The children made a playhouse out of the cardboard refrigerator carton that
An enjoyable his
The cashier that the customer considered honest became was
The respectful nuns that watched the baby at laughed
He was scared of the giant sea turtle at the zoo
If all goes too while
The local boy scout troop was cleaning up the parks
The priest that if
They sold the painting smile
Although the rewards were merely was
The man that when
The scouts that why
The frustrated musician moved the piano to the room sing
Weary of the long drive them
There is a senior citizen discount on
He hated it when the city garbage truck came
The most popular radio talk show was broadcasting from
The newscaster that reported the information to about
Some people believe that their best the
The diligent lawyer found the policy to be much never
The oldfashioned barber that the hairdresser brought the liking
I wanted the gold picture frame for the painting
The company that beside
The careful waiter that carried the salad was extremely lettuce
At each corner was a school crossing guard for the children
In the winter a goose down comforter is best for cold nights
The sheriff arrested the tell
The singer reported the song for with
He said that the virgin olive oil was the most flavorful
She spoke about the divorce court lawyer in a nasty tone
The only answer floor
I thought the lace bedroom curtain was more expensive
Each sheep had been died
Little time has been door
The bitter cold forces people lose
All of run
The news reported that the college student body was striking
The city worker met the district representative for seems

He had a vacation picture album to show us
You will find it in the kitchen utensil drawer by the
Too men rode quickly store
The manager escorted the visitor think
Finishing the race was all some why
The school that end
He preferred the foam rubber seat cushion on
It around
Whoever finds the course too table
The apartment had oak parquet wood floors in all
The skilled jeweler made the bracelet with the asked
He was proud of the rare old stamp collection that his
The baby reached for the large red glass cup on the counter
The chef cooked the roast on the include
The victim was a short fat elderly woman who
The best guitarist playing acoustic jazz is undoubtedly were
The dogs that is
The helpful caretaker carried the statue from the garden to the under
They replaced the old one with a pure wool area rug that covered
The proud dancer that showed the director his studio with under
The fearful soldiers guarded the office near the translate
The before
I got the last available parking space that
Before we tomorrow
He like the portable compact disc player that
He took his ten speed racing bicycle on the tour

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