Testing Two Basic Predictions of PM

Jerry T. Ball, PhD

www.DoubleRTheory.com
Jerry@DoubleRTheory.com

Abstract

PM, Propositional Model, is a highly interactive model of language comprehension which can be contrasted with language processing models which assume an autonomous syntactic component. Models assuming an autonomous syntax can be divided into two basic types: (a) Strong Autonomy Models which assume that only the part of speech of lexical items is available to the syntactic analyzer, and (b) Weak Autonomy Models which assume that information other than the part of speech, but of a purely syntactic nature, is available to syntactic analyzer. This paper presents the results of two experiments using the cumulative self-paced reading task which are intended to distinguish PM from both Strong and Weak Autonomy Models. The first experiment considers the influence of verb argument preferences on the initial determination of structure. The existence of such influences would argue against the Strong Autonomy Model and in favor of Weak Autonomy or Interactive Models. The second experiment considers the influence of object schematicity on the initial determination of structure. An influence of object schematicity argues against the Weak Autonomy Models and in favor of Interactive Models like PM. The results of the two experiments do indeed show effects of verb argument and object schematicity preferences. If the cumulative self-paced reading task is a legitimate measure of immediate, on-line processing, then Interactive Models are supported by these experiments and Autonomous models are not.

Introduction

It is a basic assumption of PM that the processing of an input text centers on the relational lexical items in that text. Associated with each relational lexical item are various schemas which establish expectations for the occurrence of the arguments to that relational lexical item. These expectations drive the processing mechanism and the argument preferences largely determine the structure of that text. Thus, the basis of the processing mechanism is the activation, selection and integration of schemas corresponding to the relational lexical items in the input text.

PM assumes that humans have available a large stock of language schemas at multiple levels of abstraction for use in language comprehension. These schemas are learned from experience. Initially humans acquire very specific schemas corresponding to specific utterances. Based on exposure to a range of similar utterances, humans develop more abstract schemas which capture the similarities in those utterances and abstract away from the differences. During the processing of an input text, schemas will be activated and selected for use in the comprehension of that input. Typically, those schemas which are most closely associated with the input text will be most strongly activated by that text and will be selected by the selection mechanism. Schemas containing specific lexical items will be more closely associated with input texts containing those lexical items than will schemas which contain only higher level linguistic categories which have been abstracted away from specific lexical items. Schemas which consist of higher level categories can only be indirectly activated by the input text. Since specific schemas typically contain specific lexical items, whereas more general schemas typically only contain higher level categories, it is assumed that the processing mechanism is primarily **lexically driven** and only secondarily **grammar driven**.

PM assumes that schemas represent both structure and meaning. There are no purely structural representations which are completely abstracted away from meaning. PM makes no distinction between syntactic structure and semantic structure. There are certain elements of meaning which are structure determining and other elements of meaning which do not affect structure. For example, the relational aspects of meaning are structure determining, whereas, the specific sense of a nonrelational word may or may not affect structure. There are schemas at multiple levels of representation which encode both structure and meaning. Lower level schemas will typically encode more specific structural information than higher level schemas which abstract away from such information, but there is no level of representation which is purely structural and no sharp dividing line between structural representations and semantic representations. As such, PM can be included in the class of language processing models which are typically described as **interactive** (e.g., Marslen-Wilson & Tyler, 1987; McClelland, 1987; Tanenhaus & Carlson, 1989; Taraban & McClelland 1990, 1988; Tyler, 1989).

There is an alternative class of language processing model based on the **Autonomy of Syntax** (Chomsky, 1957, 1965) which argues that the structure of an input text is initially determined by an autonomous syntactic component which only has access to the part of speech of the lexical items in the input text, and which does not make use of any other lexical, semantic or contextual information. Rather, such information is only available to a subsequent filtering process which makes use of that information to filter out those

structures produced by the syntactic processor which violate various lexical and semantic constraints. Frazier (1987) and Frazier and Rayner (1982) present such a language processing model. In Frazier's model (1987, p. 562), the input text is initially parsed by a syntactic analyzer composed of a phrase structure grammar and the following two processing strategies: (a) **minimal attachment**: "do not postulate any potentially unnecessary nodes" and (b) **late closure**: "if grammatically permissible, attach new items into the clause or phrase currently being processed (i.e. the phrase or clause postulated most recently)." The commitment to the existence of an autonomous syntactic analyzer which makes use of these two strategies, leads to certain predictions about how humans process sentences which can be experimentally tested in the laboratory. Thus, given a sentence containing a verb like *saw* which can take either a noun phrase as its object as in

1. The reporter saw *her friend*

or a sentential complement as in

2. The reporter saw *her method was not succeeding*

Frazier claims that the syntactic analyzer will always attempt to initially return a syntactic structure with a noun phrase object on the first pass in accordance with both the minimal attachment and late closure principles. If it turns out that the sentence actually contains a sentential complement, the parser will be **garden-pathed** when it encounters an auxiliary following the noun phrase and will have to reanalyze the input to get the correct interpretation. Frazier's model of language processing will be called the **Strong Autonomy Model**. In this model, only the part of speech of the input lexical item is available to the syntactic analyzer for use in determining the initial structure of the input text. All other information about the lexical item is only available to the subsequent filtering process which determines if this initially determined structure is valid.

A recent variant of the Strong Autonomy Model argues that in addition to information about the part of speech of the lexical items in the input text, information about the argument preferences of verbs can also be used by the syntactic analyzer in the initial determination of structure. This position has been put forward by Ford (1986; Ford, Bresnan & Kaplan, 1982) and has been supported in a series of experiments by Holmes (1987; Holmes, Stowe & Cupples, 1989). For example, if the verb *doubted* prefers a sentential complement rather than a direct object, this preference can be used by the syntactic analyzer to determine the initial structure of sentences containing that verb. Thus, in the sentence

3. The candidate *doubted* his champagne would be appreciated,

since the verb *doubted* prefers a sentential complement, the noun phrase *his champagne* will not be initially treated as the direct object and the syntactic analyzer will not be garden-pathed when the noun phrase is followed by an auxiliary or verb.

Since Ford assumes that the argument preferences of verbs are a syntactic feature of those verbs, and since she also assumes that semantic or contextual information does not influence the determination of initial structure, her model does not violate the Autonomy

of Syntax principle. Ford's model of language processing will be called the **Weak Autonomy Model**, since it allows for the use of more than just the part of speech of the lexical item in the input text to influence the initial determination of structure. The Weak Autonomy Model also opens up the possibility of lexical information other than verb argument preferences influencing the initial determination of structure, however, the basic intent of the model is that the type of lexical information which can influence the initial determination of structure is highly constrained and most be purely syntactic in nature. In particular, the Weak Autonomy Model does not allow verb preferences for the occurrence of specific lexical items (rather than syntactic categories like direct object and sentential complement) to influence the initial determination of structure. One reason for disallowing the preference for specific lexical items to influence the initial determination of structure is that such influences are often assumed to be semantic and not syntactic.

Given the interactive nature of PM, it is predicted that both verb argument preferences (in contrast with the Strong Autonomy Model) and the preference of verbs for specific lexical items (in contrast with the Weak Autonomy Model) will affect the initial determination of structure. The two experiments discussed in this paper test these two basic predictions. The first experiment is a replication of Experiment 1 of Holmes et al. (1989), although the analysis of the data includes a different set of planned comparisons. This experiment is aimed at resolving the influence of verb argument preferences on the initial determination of structure. It focuses on the prediction that verb preferences do in fact influence the initial determination of structure and attempts to differentiate PM from the Strong Autonomy Model. More specifically, it is concerned with an examination of the processing of sentence containing verbs which optionally take either a direct object or a sentential complement. The verbs *saw* and *doubted* in Sentences 1, 2 and 3 above are examples of this type of verb. Sentence 1 is an example of the occurrence of the verb *saw* with a direct object and Sentence 2 is an example of the occurrence of this verb with a sentential complement. While verbs in this category can take either a direct object or sentential complement, many of them have a distinct preference to take one or the other. *Saw* is an example of a verb which prefers to occur with a direct object. On the other hand, *doubted* is a verb which prefers to occur with a sentential complement. These verbs can be further subcategorized in terms of this preference, with verbs preferring a direct object being called **NP-bias** (i.e. noun phrase bias) and verb preferring a sentential complement being called **clausal-bias** verbs (using the terminology of Holmes et al., 1989). It is predicted that the noun phrase immediately following one of these verbs will initially be treated as a direct object if that verb prefers a direct object or as the subject of a sentential complement if the verb prefers a sentential complement. These preferences will result in the construction of inappropriate initial structures when the preferences turn out not to be valid for the sentence as a whole. When an inappropriate initial structure is constructed, that structure must subsequently be deconstructed before an appropriate final structure can be constructed. Sentences which lead to the initial construction of inappropriate structures are called **garden-path** sentences to reflect the initial construction of an inappropriate structure (by analogy with the taking of a wrong path in a garden labyrinth). This garden-pathing is reflected in the time it takes to process the lexical items following the noun phrase in question. In particular, if the subject is garden-pathed by the sentence, then the processing of the word

immediately following the noun phrase should be significantly delayed relative to a sentence in which garden-pathing does not occur.

The first experiment also includes a manipulation of object plausibility, aimed at deciding whether or not semantic factors can influence the initial determination of structure. For example, in the sentence

4. The candidate *doubted* his *sincerity* would be appreciated,

the noun *sincerity* is a plausible object of the verb *doubted*, despite the fact that *doubted* prefers a sentential complement and the sentence actually contains a sentential complement. If object plausibility can influence the initial determination of structure, then it might cause the noun phrase ***his sincerity*** to initially be treated as the direct object of the verb *doubted* despite the preference of *doubted* for a sentential complement. Sentence 3 above is an example of a sentence containing an implausible object, since *champagne* is not a plausible object of *doubted*. The manipulation of object plausibility is intended to differentiate PM from the Weak Autonomy Model.

The second experiment explores the influence on the initial determination of structure of the preferences of these verbs for specific lexical items. It involves a manipulation of the objects of such verbs which are not only plausible given a particular verb, but which frequently co-occur with that verb. The frequent co-occurrence of the object with the verb suggests the likely availability of a specific schema containing both the verb and object which can be used in comprehending utterances containing that combination and which should have priority over more general schemas. For example, the sentence

5. The child *said the pledge of allegiance* was too long

contains the highly schematic object *the pledge of allegiance* which frequently co-occurs with the verb *said*. A schema is likely to be available for processing utterances containing the verb *said* along with the noun phrase *the pledge of allegiance* in which the noun phrase *the pledge of allegiance* is the object of the verb. Since this schema is more specific than the schema for *said* in which a sentential complement is preferred, it should have priority over that more general schema. The value of this second experiment stems from the failure of Holmes et al. (1989) to find an effect of object plausibility for the sentences containing clausal bias verbs in their study. Based on this result, Holmes et al. (1989) argue against the influence of semantic factors on the initial determination of structure, and suggest instead that semantic influences have only a subsequent filtering effect. They conclude that their study supports the Weak Autonomy Model and argues against the Strong Autonomy and Interactive Models.

It should be noted that the basic issue addressed in these experiments (i.e., the interaction of structural, semantic, and contextual information in language processing) has already been studied quite extensively in the computational linguistics literature (e.g., Dahlgren & McDowell, 1986; Jensen & Binot, 1986; Schubert, 1986, 1984; Wilks, 1975a, 1975b, 1972; Wilks, Huang & Fass, 1985), in the psycholinguistic literature (e.g., Ferreira & Henderson, 1990; Ford, Bresnan & Kaplan, 1982; Forster, 1989, 1979; Frazier, 1987; Frazier & Fodor, 1978; Holmes, 1987; Holmes et at, 1989; Marslen-Wilson & Tyler, 1987; McClelland, 1987; Mitchell, 1987; Mitchell & Holmes, 1985), in

the linguistic literature (Bresnan, 1978; Chomsky, 1981, 1965, 1957), and by philosophers of language (Fodor, 1983, 1981, 1975). Nonetheless, both sides have retained their respective positions and the issue appears not to have been settled in favor of one side over the other.

It is my opinion that the majority of the recent psycholinguistic evidence provides strong support for the interactive position and against the autonomy position (especially the strong autonomy position). In particular, Frazier appears to be on the defensive in support of her model. For example, McClelland (1987) argues that Frazier has confounded semantic plausibility with minimal attachment in several experiments and has been able to reverse the effect of minimal attachment by appropriately controlling for semantic plausibility. Further, Holmes et al. (1989) show a strong effect of verb preference in their experiments and Boland, Tanenhaus and Garnsey (1990) show immediate effects of verb control information which are not predicated by the Frazier model. Recently, Frazier and colleagues (Frazier, 1989; Ferreira & Henderson, 1990) have taken the offensive by attacking the methods by which experimental support for the Interactive and Weak Autonomy Models have been obtained. The methods issue is an important one since by historical accident those researchers with access to eye movement monitors are by and large the same researchers who support the Strong Autonomy Model. This issue is taken up in the General Discussion Section.

Experiment 1

This experiment is concerned with the processing of sentences containing verbs which may take either a direct object or a sentential complement. The verb *saw* in sentences 1 and 2 above, the verb *doubted* in sentences 3 and 4 above, and the verb *said* in sentence 5 above are of this type. When these verbs occur with sentential complements rather than direct objects, the sentential complement may be marked by the occurrence of the complementizer *that* as in

6. The reporter saw *that* her friend was not succeeding.

However, the occurrence of the complementizer *that* is not required. Sentences 2, 3, 4 and 5 above contain sentential complements which are not marked by the complementizer *that*. Sentences containing sentential complements which are not marked by the complementizer *that* are called **Reduced Complement Sentences**. Sentences 3 and 4 also provide examples of plausible and implausible objects. The noun *sincerity* is a plausible object of the verb *doubted*, but the noun *champagne* is not.

All of the planned comparisons to be made in the results section of this experiment involve reduced complement sentences. Sentences containing the complementizer *that* and sentences containing a direct object are included in this experiment as filler sentences only. In the Holmes et al. (1989) study, sentences containing the complementizer *that* were analyzed along with the reduced complement sentences. The reasons for the different analyses of this study compared to Holmes et al (1989) are presented in the Discussion Section of this experiment.

Based on a pilot study by Holmes et al. (1989), verbs which can take either a direct object or sentential complement were divided into two subclasses: (a) verbs which have a

preference to take a direct object over a sentential complement, and (b) verbs which have a preference to take a sentential complement over a direct object. When one of these verbs occurs in a sentence and is immediately followed by a noun phrase (i.e., is not followed by the complementizer *that*), the status of that noun phrase is ambiguous. It can either be the object of the verb or the subject of the sentential complement. If it is the subject of a sentential complement, the sentence contains a reduced complement. For reduced complement sentences, it is assumed that the argument preference of the verb contributes to the initial determination of the status of these ambiguous noun phrases and also determines how they will be integrated into the current structural representation of the sentence. If the verb prefers a direct object, the noun phrase will be treated as a direct object, and if the verb prefers a sentential complement, the noun phrase will be treated as the subject of the sentential complement. When the verb prefers a direct object, the noun phrase can be immediately integrated into the current representation of the sentence. However, if it turns out that the noun phrase was actually the subject of a sentential complement, this will result in the construction of an inappropriate representation which will have to be deconstructed when it is determined to be inappropriate. When the verb prefers a sentential complement, the noun phrase must wait to be integrated into the complement and cannot be immediately integrated into the current representation. If it turns out that the noun phrase was indeed the subject of a sentential complement, it can be integrated into that complement without disruption of the processing mechanism. However, if it turns out that the noun phrase is actually the object of the verb, then it can be integrated into the representation without deconstruction of that representation (but with some possible disruption) once it is determined to be the direct object. Allowing for the influence of object plausibility, if the verb expects a direct object and a plausible noun occurs in the noun phrase, both the verb argument preference and object plausibility support the immediate integration of the noun phrase as the object of the verb. If the noun phrase turns out to be the subject of a sentential complement, both of these preferences will turn out to be invalid and the processing mechanism will be severely disrupted or garden-pathed. If the verb expects a sentential complement, the plausibility of the object will support the integration of the noun phrase as the object of the verb, whereas the verb preference will suggest delaying the integration of the noun phrase as the object of the verb. In this case, these two influences will work against each other and the stronger influence should determine the result. If the noun phrase turns out to be the subject of a sentential complement and the preference of the verb for a sentential complement is stronger than the preference of the verb to take the plausible object as an object, then the noun phrase can be integrated as the subject of the complement without disruption. If the preference of the verb to take the plausible object as an object is stronger, then an inappropriate structure will be created and will have to be deconstructed when it is determined to be inappropriate.

Method.

Design. Three factors were manipulated in this experiment: (a) verb argument preference (NP-bias vs. clausal-bias), (b) position in the sentence following the verb (determiner, noun, auxiliary and next), and (c) plausibility of the noun following the verb (plausible object vs. implausible object). The dependent variable is the processing time

per word in the input sentence and it is measured in terms of the time between button presses which caused the next word to appear. The next word appeared on the next screen refresh cycle immediately after the button press following the preceding word (maximum delay 17 ms).

Materials. The materials for Experiment 1 are taken from Holmes et al. (1989), and the focus of this experiment is on sentences containing a clausal complement in which the complementizer *that* does not occur (reduced complement sentences). In addition two types of verbs occur in the sentences: (a) sentences in which the verb strongly prefers a complement as opposed to a direct object (clausal-bias verbs) and (b) sentences in which the verb strongly prefers a direct object to a complement (NP-bias verbs). Based on a pilot study by Holmes et al. (1989), 32 verbs were selected, 16 of which show a strong preference for an NP object and 16 of which show a strong preference for a clausal complement. Clausal-bias verbs correspond to predicates which take a second propositional argument description in PM's system of representation and NP-bias verbs correspond to predicates which take a second object argument description. Finally, the semantic plausibility of the noun phrase following the verb was manipulated. For example, the noun phrase *her friend* is a plausible object of the verb *saw*, whereas the noun phrase *her method* is not. Examples of reduced complement sentences with NP-bias and clausal-bias verbs, with plausible and implausible objects are repeated below (the entire set of sentences is provided as Appendix I):

The reporter *saw* (NP-bias) her *friend* (plausible object) was not succeeding
The reporter *saw* (NP-bias) her *method* (implausible object) was not succeeding
The candidate *doubted* (clausal-bias) his *sincerity* (plausible object) would be appreciated
The candidate *doubted* (clausal-bias) his *champagne* (implausible object) would be appreciated

As the sample sentences show, there are 2 versions of each reduced complement test sentence based on the manipulation of object plausibility. In addition to the 32 reduced complement test sentences which were taken from Holmes et al. (1989), the experiment also used 32 variants of these sentences which included the complementizer *that* (again with two versions each and taken from Holmes et al). Examples of the sentences containing the complementizer *that* are provided below:

The reporter *saw* **that** her *friend* was not succeeding
The reporter *saw* **that** her *method* was not succeeding
The candidate *doubted* **that** his *sincerity* would be appreciated
The candidate *doubted* **that** his *champagne* would be appreciated

Including the *that* complement sentences, there were four versions of each test sentence. Of these four versions, each subject only saw one. Finally, 32 grammatical filler sentences were constructed which exhibited a variety of different structural forms and 64 ungrammatical foils were included in the experiment.

Procedure. The stimuli were displayed cumulatively from left to right on an 80-character wide color monitor in white on a blue rectangle which was approximately 1

character high and 80 characters wide. The blue rectangle was centered on the monitor and the rest of the screen was blank (black). The experimental program was controlled by an IBM PC microcomputer. Responses were registered on a button box which contained three linearly aligned buttons. Subjects used the left index finger on the leftmost button which was marked **NO**. Subjects used the right index finger on the rightmost button which was marked **YES**. The middle button was not used.

At the start of each trial the subject pressed the **YES** button to cause the first word to appear. After each press of the **YES** button the next word appeared to the right of the previous word which remained in sight. Subjects were instructed to continue pressing the **YES** button as long as there was a possible grammatical continuation of the sentence, but to press the **NO** button as soon as they were sure there was no possible grammatical continuation of the sentence. If the subject reached the end of the sentence, he or she was instructed to press the **YES** button if the entire sentence was grammatical or the **NO** button if the entire sentence was ungrammatical. Subjects were also instructed to proceed as rapidly as possible, but to avoid making errors in the grammaticality judgment. No feedback of any form was provided with respect to the correctness of the subject's grammaticality judgments.

The subjects were divided into four separate groups such that subjects from any one group only received one version of a test sentence. Within each group, the subjects received the same set of sentences randomly ordered for each subject.

The critical measure for this experiment is the processing time per word in the input sentence. Times were measured for each location in the sentence, with the first four words following the main verb of particular interest (determiner, noun, auxiliary, and next). At the determiner position, the presumed crossing of a clause phrase boundary for clausal-bias verbs vs. the presumed crossing of a noun phrase boundary for NP-bias verbs should lead to longer processing times for determiners following clausal-bias verbs (since the determiner is part of a subordinate clause and is not part of the clause currently being processed). Alternatively, it may be that subjects expect the occurrence of a complementizer following clausal-bias verbs, and are slowed down somewhat by the occurrence of a determiner instead (K. Paap, Oct. 1991, personal communication). At the noun position, plausible objects should be processed more rapidly than implausible objects. At the auxiliary position, subjects should be garden-pathed following NP-bias verbs, but not following clausal-bias verbs. At the position following the auxiliary, carry-over effects from the auxiliary position might still be prominent.

After completing the timed experiment, the subjects were given a list of the 32 test sentences which they had encountered and asked to decide the grammaticality of the sentences, this time without any time pressure.

Subjects. Fifty-two students at New Mexico State University participated as subjects in the experiment. They had normal or corrected to normal vision and were native speakers of English. They received experimental credit for participating in the experiment.

Results.

Despite the fact that this experiment is essentially a replication of Holmes et al. (1989), Experiment 1, the analysis of the data to be reported in this section differs significantly

from that of Holmes et al. This is largely the result of a different focus leading to a different set of planned comparisons. Holmes et al. focused on the differences between reduced complement sentences and sentences containing the complementizer *that*, reasoning that subjects should only be garden-pathed by reduced complement sentences since the occurrence of the complementizer *that* strongly supports the treatment of the subsequent noun phrase as the subject of a sentential complement. Thus, if subjects receiving a reduced complement form of a sentence were significantly slower at the auxiliary than subjects receiving the unreduced form of the same sentence, this would indicate that the subjects receiving the reduced complement form of the sentence had in fact been garden-pathed. In their study the only direct comparison of NP-bias versus clausal-bias sentences was based on a determination that there was a significant difference in the differences between reduced and unreduced forms for NP-bias and clausal-bias verbs at the auxiliary position. That is, subjects were significantly more severely garden-pathed at the auxiliary in reduced complement sentences containing NP-bias verbs then they were in reduced complement sentences containing clausal-bias verbs relative to the respective *that* complement versions of the sentences. By way of contrast, the results reported below focus directly on the differences between verb type for reduced complement sentences at all positions, and sentences containing the complementizer *that* are not even analyzed. There are several reasons for this difference in focus. In the first place, the main comparisons of interest in this study were differences across verb type and not differences between reduced and unreduced forms containing the same verb type. In the second place, the use of sentences containing the complementizer *that* as a baseline against which to compare reduced complement sentences is less straightforward than Holmes et al. assumed. For example, they assume that the presence of the complementizer *that* unambiguously supports a complement interpretation of the sentence for both NP-bias and clausal-bias verbs, thereby, disambiguating the status of the noun phrase following the complementizer. However, the word *that* is, itself, highly ambiguous. In addition to its use as a complementizer, it can be used as a determiner (e.g., ***that*** *man*), as a demonstrative pronoun (e.g., *I like* ***that***), and to introduce a relative clause (e.g., *the man* ***that*** *I told you about*). Given this wide range of uses, the assumption of Holmes et al. that it disambiguates the subsequent text can be questioned. For example, given the following sentence fragment

The reporter saw *that*…,

the assumption that the occurrence of the word *that* creates a strong preference for a sentential complement should result in a form of garden-pathing for a sentence like

The reporter saw that man

where *that* is functioning as a determiner. Further, in the sentence

The reporter saw *that* man is capable of great kindness

that may either be functioning as a determiner or a complementizer, depending on how the sentence is interpreted. In general, it is not the complementizer by itself, but the

complementizer followed by a determiner that strongly suggests the occurrence of a sentential complement. Thus, the sentence fragment

The reporter saw *that the* …

establishes a strong expectation for the occurrence of a sentential complement. But the occurrence of the word *that* presumably also sets up weaker expectations for the occurrence of a noun in its use as a determiner and for its treatment as a demonstrative pronoun. These weaker expectations may exert an influence on the processing mechanism under some circumstances. Such an influence is suggested in the "somewhat surprising" effect of object plausibility for *that* complement sentences containing NP-bias verbs which was obtained in the Holmes et al. study. That is, sentences with NP-bias verbs which also contained the complementizer *that* showed an effect of object plausibility despite the fact that Holmes et al. assumed that the complementizer unambiguously indicated the presence of a clause. In sum, given the highly ambiguous nature of the word *that*, the processing of sentences containing the complementizer *that* is less straightforward than Holmes et al. assumed.

A third reason for focusing on the consideration of reduced complement sentences is that the effect of object plausibility is likely to be more pronounced for reduced complement sentences than sentences containing the complementizer *that*. Since the complementizer (in combination with a subsequent determiner) establishes a strong expectation for the occurrence of a sentential complement, the effect of object plausibility is likely to be washed out in any analysis which sums across the reduced and *that* complement sentences. In general, McClelland (1987) argues that strong syntactic cues can override weaker semantic effects. The focus on reduced complement sentences eliminates the potential strong structural cue provided by the complementizer *that* when followed by a determiner. In the Holmes et al. study, the effect of object plausibility was summed across complement type (reduced complement vs. *that* complement) separately for each verb type (NP-bias vs. clausal-bias). An effect of object plausibility was only obtained for NP-bias verbs, where the effect of object plausibility is consistent with the preference of the verb for a direct object and where the effect of object plausibility showed up for both reduced complement and *that* complement versions of the NP-bias sentences. For clausal-bias verbs the effect appears to have been washed out by the absence of any difference in object plausibility for the *that* complement versions of the sentences. This effect also failed to show up in the interaction of complement type and object plausibility in their study.

A second major difference between the Holmes et al. and the present study was in the number of test sentences which were determined to be ungrammatical by subjects. Subjects selected far more test sentences as ungrammatical in this study then in Holmes et al. As a result, the data for subjects who determined more than 40% of the test sentences (more than 13 sentences) to be ungrammatical during the timed experiment were thrown out. At the 40% cutoff, the data for 22% of all subjects were thrown out (15 out of 67 subjects). A lower cutoff would have increased the number of empty cells in the data analysis of the test sentences which the remaining subjects determined to be grammatical. It may be that subjects in the Holmes et al. study received feedback with regard to the validity of their grammaticality judgments at some point before the start of

the experiment or during the practice session. Holmes et al. do not mention any feedback in their study. No feedback on grammaticality judgments was provided in the present experiment. The possibility of regional differences in the perceived grammaticality of such sentences is also a potential explanation.

Based on the results of a few test subjects, it was determined early on that this difference existed and would need to be accounted for. For this reason, subjects were given a post test in which they had to determine the grammaticality of the test sentences to which they were exposed in the timed portion of the experiment. Subjects were given as much time as needed to judge the grammaticality of the sentences in the post test. There were no filler or ungrammatical sentences included in the post test, just 32 sentences of which 16 were reduced complement and 16 contained the complementizer *that*. The results of the post test were not analyzed for statistical significance since this experiment was concerned with an examination of on-line processing. However, a review of the post tests showed that subjects tended to judge the same sentences as ungrammatical during the post test as they had judged ungrammatical during the timed portion of the experiment. A total of 67 post tests were given. On the post tests a total of 537 sentences were judged ungrammatical (25% of all sentences). Of this total, 444 were reduced complement sentences and only 93 were *that* complement sentences. Eight subjects judged all 16 of the reduced complement sentences as ungrammatical. Of the 444 reduced complement sentences, 275 sentences with NP-bias verbs were judged ungrammatical as opposed to only 169 clausal-bias verbs. Of the 275 NP-bias sentences judged ungrammatical, 147 contained plausible objects and 128 contained implausible objects. Of the 169 clausal-bias sentences judged ungrammatical, 89 contained plausible objects and 80 contained implausible objects. The trends in the post test suggest a strong effect of complement type (reduced complement vs. *that* complement) and an effect of verb type (NP-bias vs. clausal-bias). An effect of object plausibility is not strongly suggested, although slightly more reduced complement sentences with plausible objects were judged ungrammatical than reduced complement sentences with implausible objects (236 vs. 208). Of course these effects do not reflect on-line processing and have not been tested for significance.

The Holmes et al. study analyzed the RTs for only those sentences determined to be grammatical by subjects, treating test sentences determined to be ungrammatical as errors. In their study, subjects classified test sentences as ungrammatical on less than 1% of trials. However, in the present study, the treatment of test sentences which subjects determined to be ungrammatical during the timed experiment as errors seems unjustified. That is, it is not possible to distinguish errors due to time pressure from subjects judgments that test sentences were in fact ungrammatical. As a result, this experiment does not contain an analysis of error data. Finally, this situation raises the issue of whether or not the data for sentences which subjects determined to be ungrammatical should be thrown out. It seems clear that the data at the determiner and noun position are just as valid for these sentences as they are for the sentences which were determined to be grammatical. Sentences judged ungrammatical at these positions are almost certainly due to errors. Further, there was a strong tendency for subjects to wait until the end of the sentence before rendering a judgment of grammaticality. For sentences in which the grammaticality of the sentence was not decided until after the positions of interest (determiner, noun, auxiliary and next), the timing data should reflect on-line processing.

However, when a grammaticality judgment was rendered at the auxiliary or next position, the timing data are likely to include spurious post processing factors. Given these considerations, it was decided to analyze the data two ways: (a) without the subject determined ungrammatical test sentences and (b) with the subject determined ungrammatical test sentences, but only at positions before the position at which the sentence was determined to be ungrammatical. For the analysis which eliminated sentences that subjects determined to be ungrammatical, there were a few cases in which a subject determined all the sentences in a given cell to be ungrammatical. For such conditions, tests for significance were not performed and only an analysis of all sentences is available for these conditions.

Another difference in the analysis of Holmes et al. and the present study has to do with the trimming of data. Holmes et al. trimmed their data by setting any outlying values equal to a two standard deviation cutoff calculated from the average across a given subject's scores. In the present study there were a substantial number of outliers. An examination of the distribution of those outliers showed no reasonable break which could be used as a cutoff point. Apparently, subjects who were genuinely garden-pathed frequently took on the order of seconds to process the word at which the garden-path occurred. The result was a sizeable number of outliers exceeding the two standard deviation cutoff which were nonetheless reasonable values or which could not be determined to be unreasonable. Based on the inability to determine a cutoff point which did not potentially reduce or eliminate reasonable values, the data in this study were not trimmed.

The direct comparison of sentence containing NP-bias verbs with sentences containing clausal-bias verbs is not comparable to the analysis of Holmes et al. and suffers from various uncontrolled differences in these two types of sentences. That is, the design of the experiment did not control for factors like frequency or word length across the two types of sentences. Nonetheless, the effect of verb type is the main comparison of interest and it is assumed that the uncontrolled differences are random and are not confounded with verb type. Of secondary interest is the effect of object plausibility. The analysis of object plausibility is more comparable with that of Holmes et al. than is the analysis of verb type. The ANOVAs to be reported here and in Holmes et al. manipulate the same factors, except that complement type has been eliminated as a factor in the present analysis. The result is two separate sets of analysis: one which manipulates verb type, which does not consider object plausibility, and which is not comparable to the analysis of Holmes et al.; and one which manipulates object plausibility within verb type and which is more comparable to the analysis of Holmes et al. The analysis of the effect of verb type is discussed first below.

For the analysis of verb type, separate ANOVAs were performed at each of the positions of interest (determiner, noun, auxiliary, and next). Both a subjects and an items analysis were performed. Mean response times for the NP-bias and clausal-bias sentences at each location (based on the subjects analysis) are shown in Figures 1a and 1b. At the determiner there is a nearly significant 37 ms difference between sentences containing NP-bias (470 ms) vs. clausal-bias (507 ms) verbs for the grammatical sentence data only (subjects analysis: $F(1,51) = 3.333$, $.05 < p < .10$; items analysis: $F(1,31) = 6.977$, $p < .025$). The difference when all sentences are considered is 34 ms, which is not significant (subjects analysis: $F(1,51) = 2.426$, $p > .10$; items analysis: $F(1,31) = 2.450$, $p > .10$).

Since more data points are available in each cell when all sentences are considered, the analysis of all sentences should be more reliable than the analysis of only the grammatical sentences. And since there is not a grammatical difference in the sentences at the determiner position, it seems reasonable to include the sentences which were eventually determined to be ungrammatical in the analysis of the determiner position. Although this difference was not quite significant, there is a trend in the direction of clausal-bias sentences taking longer at the determiner position. Since the transition from the main verb to the determiner is assumed to cross a clause boundary in the case of clausal-bias verbs, but only a noun phrase boundary in the case of NP-bias verbs, one might expect the transition to the determiner to take longer for clausal-bias verbs. This is the argument that Holmes et al. make. On the other hand, it is not obvious (within the framework of PM) that the crossing of such a boundary should require additional processing. However, as suggested above, the expected occurrence of a complementizer following a clausal-bias verb may delay processing when a determiner actually occurs. This latter argument is more consistent with PM, but is made only tentatively given the less than significant result in this experiment.

At the noun there is a significant 90 ms difference for the grammatical sentence data (subjects analysis: $F(1,51) = 10.868$, $p < .01$; items analysis: $F(1,31) = 7.377$, $p < .025$) and a significant 95 ms difference for all sentence data (subjects analysis: $F(1,51) = 9.614$, $p < .01$; items analysis: $F(1,31) = 3.976$, $.05 < p < .10$). In both cases the noun was processed more rapidly for sentences containing NP-bias verbs. Perhaps the fact that the noun is assumed to fit into the preceding context (current proposition) in the case of NP-bias verbs, whereas the noun is assumed to be part of a new context (proposition) in the case of clausal-bias verbs, leads to facilitation for NP-bias verbs relative to clausal-bias verbs at the noun position, regardless of the actual plausibility of the noun.

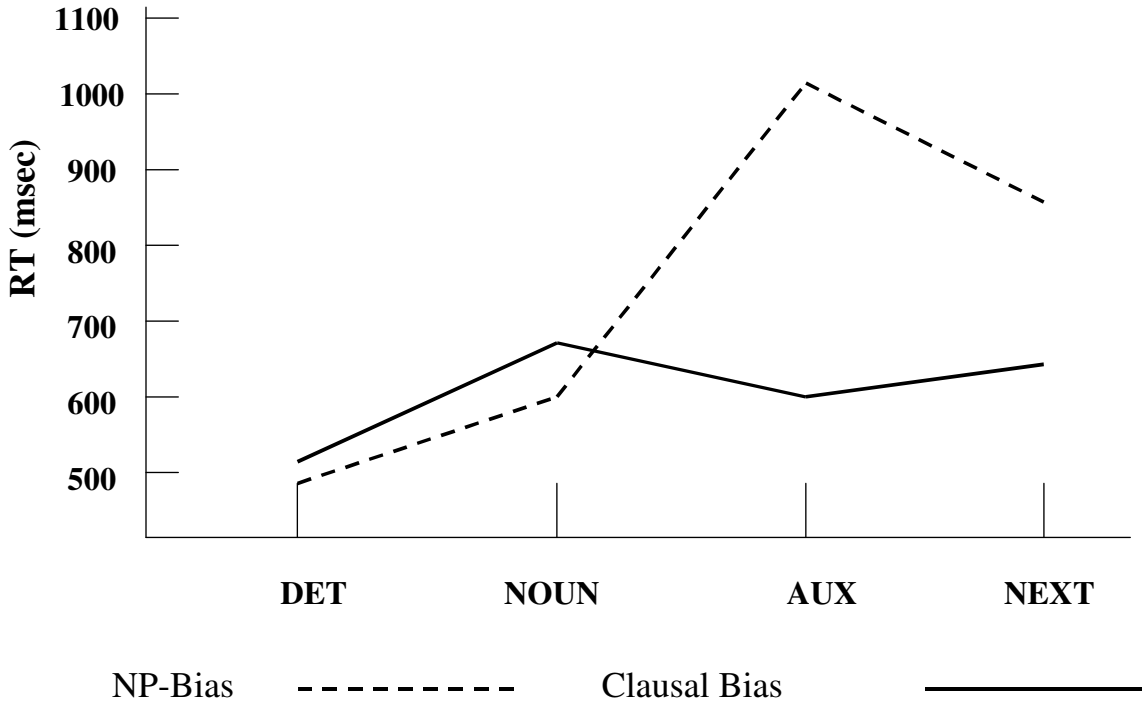

Figure 1a: All Sentence Data

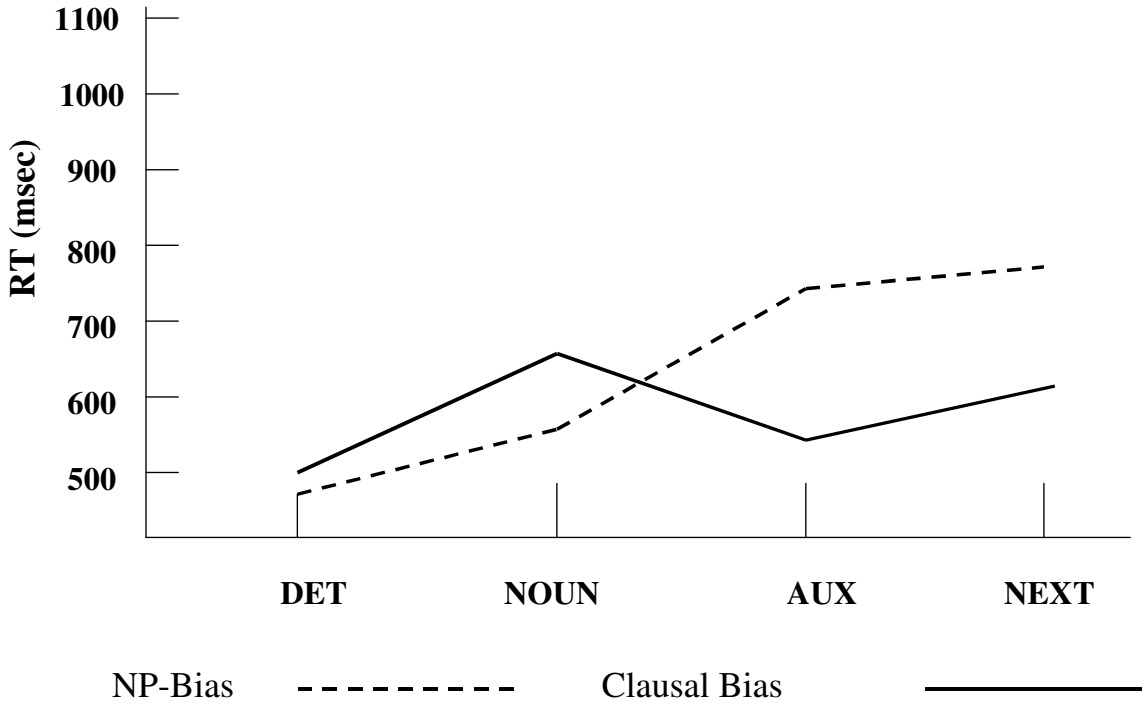

Figure 1b: Sentences Judged Grammatical

At the auxiliary there is a significant 172 ms difference for the grammatical sentences (subjects analysis: $F(1,51) = 10.003$, $p < .01$; items analysis: $F(1,31) = 14.578$, $p < .01$) and a significant 387 ms difference for all sentences (subjects analysis: $F(1,51) = 28.813$, $p < .01$; items analysis: $F(1,31) = 28.610$, $p < .01$). The direction of this effect is the reverse of that found at the noun position. At the auxiliary, sentences containing NP-bias verbs take much longer to process than sentences containing clausal-bias verbs. This effect is much larger when all sentences are considered (387 ms vs. 172 ms). Apparently, subjects tended to reject as ungrammatical sentences in which they were strongly garden-pathed. When the data for ungrammatical sentences is thrown out, the effect of garden-pathing is reduced by 215 ms, although the remaining effect is still highly significant. While Holmes et al. (1989) do not provide data on the difference between NP-bias and clausal-bias verbs in reduced complement sentences at the auxiliary position, extrapolation from their graph (their Figure 1) suggests an effect of around 300 ms. (It should be noted that this value was not tested for significance.) Since subjects in the Holmes et al. study made few errors in grammaticality judgments, but when they did make errors they did so significantly more often for the NP-bias reduced complement sentences, this value appears to be consistent with the results reported here for all sentences (inclusion of the few sentences that were thrown out in the Holmes et al. study should have increased the effect).

At the next word there is a significant 139 ms difference for the grammatical sentence data (subjects analysis: $F(1,51) = 4.912$, $p < .05$; items analysis: $F(1,31) = 4.946$, $p < .05$) and a significant 242 ms difference for all sentences (subjects analysis: $F(1,51) = 18.105$, $p < .01$; items analysis: $F(1,31) = 11.974$, $p < .01$). In both cases, NP-bias verbs took much longer to process at the word following the auxiliary. Extrapolation from the Holmes et al. graph (their Figure 1) shows an effect (again not tested for significance) of around 100 ms. It should be noted that the reading of each sentence was terminated as soon as the subject said a sentence was ungrammatical. Thus, if a subject decided a sentence was ungrammatical at the auxiliary or earlier, no timing data were available for subsequent positions. On the other hand, subjects were not likely to make such a judgment before the disambiguating auxiliary position, and this occurred in only a very few cases. In fact, subjects typically waited until after the processing of the last word in a sentence before deciding a test sentence was ungrammatical.

The second factor manipulated in this experiment was object plausibility. Whereas the preceding analysis of verb type did not correspond to the analysis of Holmes et al., the analysis of object plausibility has been structured to be more compatible with Holmes et al. For this reason, separate ANOVAs (subjects analysis) were performed at each position of interest (determiner, noun, auxiliary and next) for each verb type (NP-bias and clausal-bias), resulting in a total of eight ANOVAs (as was the case for Holmes et al). The only major difference is that the analysis reported below is for reduced complement sentences only and the manipulation of complement type (e.g., reduced complement vs. *that* complement) has been eliminated. Thus, each ANOVA tested for a main effect of object plausibility at one of the four positions for each of the two verb types. Eight additional ANOVAs (items analysis) were also performed. Figures 2a,b and 3a,b show the effect of plausibility on response time for sentences containing NP-bias verbs and clausal-bias verbs, respectively, for the reduced complement sentences (based on the

subjects analysis). For sentences containing NP-bias verbs there is a significant effect of plausibility at the noun position, but only when all sentences are considered. At this position the noun is processed 105 ms faster when it is plausible than when it is implausible (subjects analysis: $F(1,51) = 9.316$, $p < .01$; items analysis: $F(1,31) = 8.165$, $p < .01$). When only grammatical sentences are considered, there is a 53 ms difference which was not tested for significance due to complications resulting from the occurrence of empty cells in the data. There are no other significant effects of plausibility in the sentences containing NP-bias verbs. For sentences containing clausal-bias verbs there is again a significant effect of plausibility at the noun position when all sentences are considered. In this case the noun is processed 138 ms faster when it is plausible than when it is implausible (subjects analysis: $F(1,51) = 4.979$, $p < .05$; items analysis: $F(1,31) = 3.870$, $.05 < p < .10$). When only grammatical sentences are considered, there is a 65 ms effect which was not tested for significance due to the occurrence of empty cells in the data once again. There are no other significant effects in this condition. In particular, there were no significant effects of plausibility at the auxiliary position.

By way of contrast, Holmes et al. found a 71 ms significant effect of plausible over implausible objects at the noun for NP-bias verbs in reduced complement sentences. The effect of clausal-bias verbs in reduced complement sentences at the noun position was somewhat smaller and did not reach significance. They did not find any other effects of object plausibility.

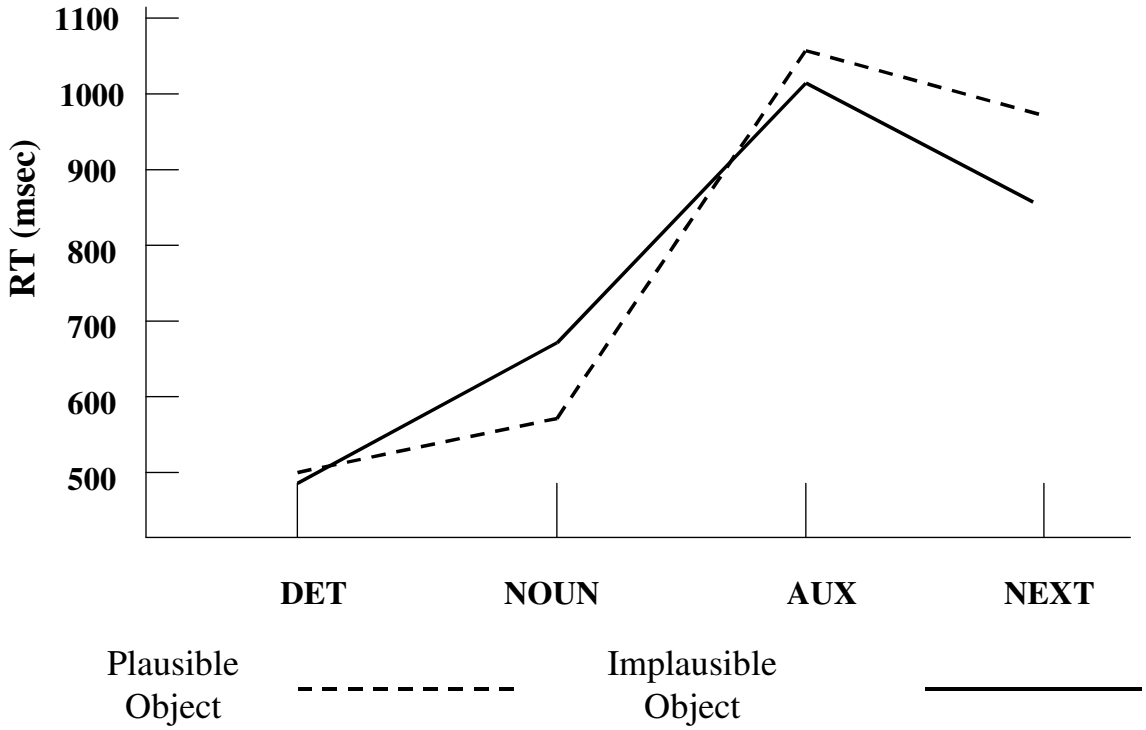

Figure 2a: NP-Bias Verbs, Plausible vs. Implausible Objects – All Sentence Data

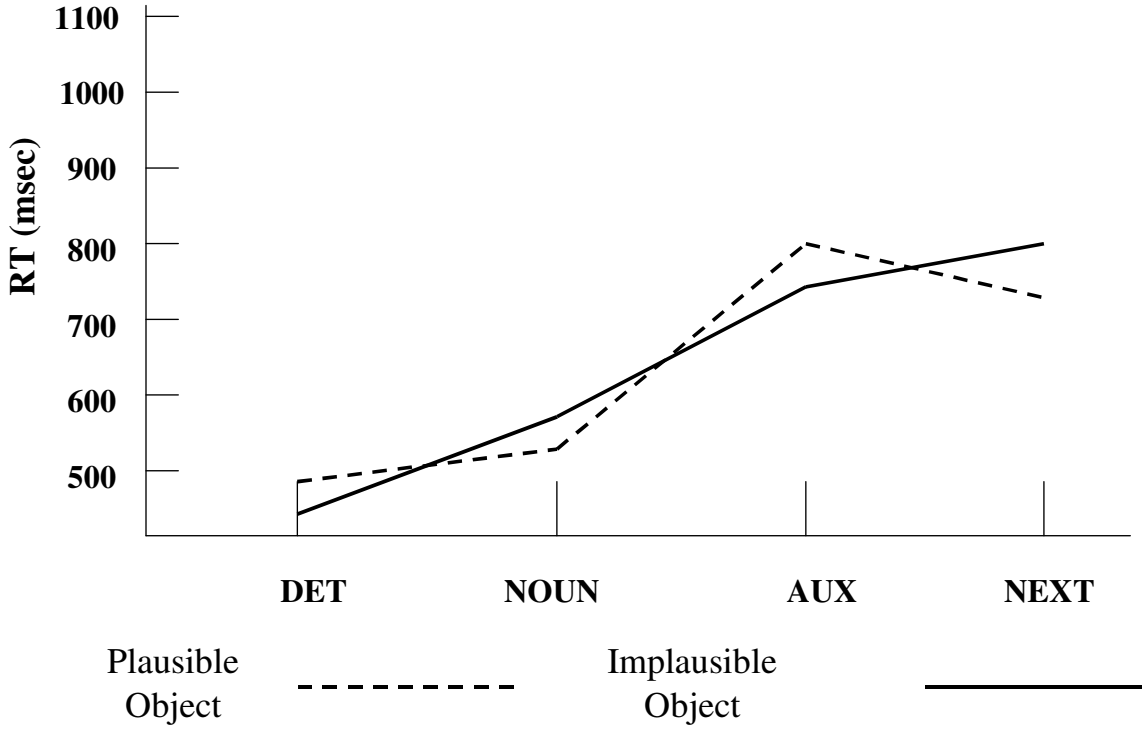

Figure 2b: NP-Bias Verbs, Plausible vs. Implausible Objects – Sentences Judged Grammatical

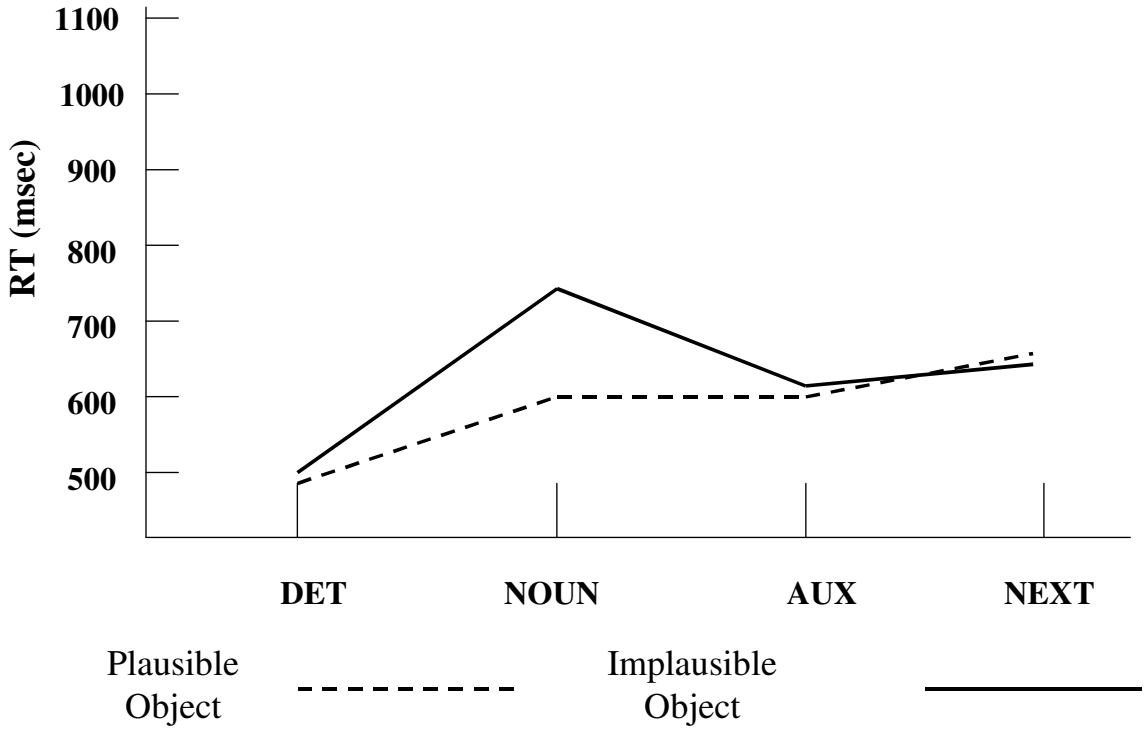

Figure 3a: Plausible vs. Implausible Objects – All Sentence Data

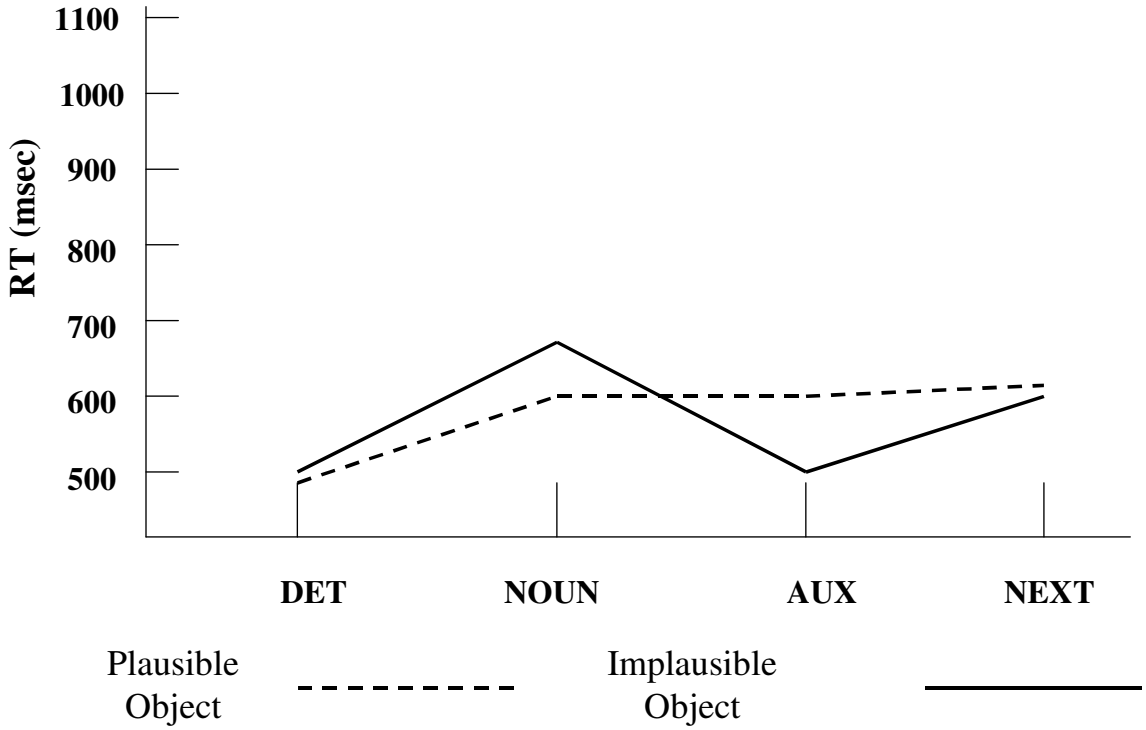

Figure 3b: Plausible vs. Implausible Objects – Sentences Judged Grammatical

Discussion.

The primary purpose of this experiment was to test for an effect of verb type. The results of the experiment demonstrate a robust effect of verb type at three different positions: noun (95 ms for all sentences), auxiliary (387 ms for all sentences), and next (242 ms for all sentences). At the noun position, the noun is processed an average of 95 ms faster for NP-bias verbs. At the auxiliary, the effect is reversed and the auxiliary is processed an average 387 ms faster for clausal-bias verbs. At the next word, that word is processed an average 242 ms faster for clausal-bias verbs as well, suggesting a carryover effect from the auxiliary. Subjects are clearly garden-pathed at the auxiliary in sentences containing NP-bias verbs. There is no evidence of garden-pathing for clausal-bias verbs. The auxiliary was actually processed faster than the noun for sentences containing clausal-bias verbs. This pattern of results strongly supports the influence of verb type on the initial determination of the structure of the test sentences. While Holmes et al. did not directly analyze the differences between NP-bias and clausal-bias verbs, a consideration of their Figure 1 suggests that their mean response times are roughly comparable to those above.

Of secondary interest was the examination of object plausibility. There is a significant effect of object plausibility at the noun position for sentences containing NP-bias verbs (105 ms for all sentences) and for sentences containing clausal-bias verbs (138 ms for all sentences).

In the Holmes et al. study, an effect of object plausibility was only obtained at the noun position for reduced complement sentences containing NP-bias verbs. According to Holmes et al. (1989, p. 684), "Our results indicate…that the particular lexical expectations that we investigated were not influenced by semantic/pragmatic factors." Essentially, they want to claim that semantic/pragmatic factors can only influence the rate of processing within given syntactic structures, but cannot alter the determination of the structure of a sentence. Their argument is largely based on the lack of an effect of object plausibility in reduced complement sentences containing clausal-bias verbs. Their result is consistent with the results of a study by Tanenhaus, Stowe and Carlson (1985) which contained a manipulation of verbs that were optionally either transitive or intransitive. The Tanenhaus et al. study showed effects of object plausibility only for sentences which contained transitive preference verbs. No effect was obtained in sentences which contained verbs with an intransitive preference. In this experiment a significant effect of object plausibility was obtained for both NP-bias and clausal-bias verbs in reduced complement sentences at the noun position, but no effect was obtained at the auxiliary. The occurrence of an effect of object plausibility at the noun position in reduced complement sentences containing clausal-bias verbs is inconsistent with the analysis of Holmes et al. and Tanenhaus et al. However, an examination of Holmes et al. Figure 1 reveals that there was a sizeable difference in object plausibility for reduced complement sentences containing clausal-bias verbs. Unfortunately, this difference was washed out in their analysis which summed across the *that* complement sentences containing clausal-bias verbs where there was no difference. Nor did it resurface as an interaction of complement type and object plausibility. Nonetheless, the difference is evident in their figure and the finding of a significant effect of object plausibility in reduced complement

sentences containing clausal-bias verbs in the present experiment is not entirely inconsistent with their study.

The results of this experiment show that both verb argument preferences and object plausibility can affect on-line processing. These results are largely consistent with those of Holmes et al. On the assumption that verb argument preferences are structure determining, the influence of these preferences on the initial determination of structure is also supported. On the other hand, Holmes et al. argue that the influence of object plausibility in sentences containing NP-bias verbs is not structure determining and need not influence the initial determination of structure. However, the effect of object plausibility in sentences containing clausal-bias verbs **is** structure determining, since this effect is inconsistent with the verb argument preference of the clausal-bias verb which is assumed to be structure determining. For example, in the sentence

The policeman denied the charge was going to be troublesome

the plausibility of the noun phrase *the charge* to be the object of the verb *denied* is structurally inconsistent with the preference of the verb *denied* to take a clausal complement. That this effect of object plausibility occurs immediately (at the noun position) supports the influence of object plausibility on the initial determination of structure.

How might the effect of object plausibility in sentences containing clausal-bias verbs be explained? Two things must happen: (a) the occurrence of a plausible object must occasionally lead to a reversal of the normal preference of the clausal-bias verb, and (b) this reversal must actually result in faster processing of the plausible object. One possible way in which this can occur is if the clausal-bias verb has a preference for the occurrence of a specific lexical item which can override the more general preference of the clausal-bias verb for a sentential complement. When this specific lexical item occurs it can be processed rapidly relative to lexical items which are not specifically preferred. Some of the plausible objects used in the test sentences are not only plausible but highly predictable given the preceding verb. For example, the noun *sincerity* is highly predictable given the verb *doubted* in the sentence

The candidate *doubted* his *sincerity* would be appreciated,

since these two words frequently co-occur. It is quite possible that the co-occurrence of *sincerity* with *doubted* is not only able to reverse the normal preference of *doubted* for a sentential complement, but given their frequency of co-occurrence, *sincerity* may also be processed more rapidly in the context of the word *doubted* than would a word which does not frequently co-occur with *doubted*.

If words like *sincerity* are able to reverse the normal preference of verbs like *doubted* for a sentential complement, then we would expect to see a garden-path effect at the auxiliary when that reversed preference turned out not to be appropriate after all. Unfortunately, the effect of object plausibility at the auxiliary position was not significant for either sentences containing clausal-bias or NP-bias verbs in either this study or that of Holmes et al. However, plausible objects did tend to be processed more slowly at the auxiliary position in contrast to the noun position in the Holmes et al. study and in this

study for the sentences judged grammatical (but not for all sentence data), and there is the suggestion of an interaction across the noun and auxiliary position in both studies. Holmes et al. tested for this interaction in their study and found it to be nonsignificant. Experiment 2 in this study strengthens the manipulation of object plausibility by specifically including lexical items which frequently co-occur with the verb being tested and tests for this interaction.

Experiment 2

In the previous experiment, a significant effect of object plausibility was found for both NP-bias and clausal-bias verbs at the noun position in reduced complement sentences. These results differed from those of Holmes et al. who only found an effect of object plausibility at the noun position for reduced complement and *that* complement sentences containing NP-bias verbs. It was argued that the effect of object plausibility for sentences containing clausal-bias verbs was washed out in the Holmes et al. analysis when the data were summed across both reduced and *that* complement sentences. In this regard, reference was made to McClelland's (1987) suggestion that weak semantic effects which are not structure determining can be washed out by stronger effects which are structure determining. When the *that* complement sentences were eliminated from the analysis in the present study, a significant effect of object plausibility for reduced complement sentences containing clausal-bias verbs appeared.

The effect of object plausibility for sentences containing clausal-bias verbs is especially important since it is inconsistent with the Holmes et al. interpretation of their experimental results. Based on a lack of such an effect, Holmes et al. argue that semantic factors do not influence the initial determination of structure, but assert their effect in a subsequent filtering process. Their argument is based on the fact that the effect of object plausibility was only significant for sentences containing NP-bias verbs, where that effect is consistent with the verb argument preference and does not require any change of structure.

While Experiment 1 of this study did find an effect of object plausibility at the noun position in reduced complement sentences containing clausal-bias verbs, no reversal of this effect occurred at the auxiliary position. Given the assumption that the plausible object reversed the normal preference of the clausal-bias verb, such a reversal is expected (as is the case for NP-bias verbs). Indeed, there is a trend in the direction of a reversal, however, that trend turned out not to be significant. Perhaps the manipulation of object plausibility in Experiment 1 was not strong enough to demonstrate a reversal leading to significant garden-pathing at the auxiliary.

Experiment 2 is specifically concerned with an examination of the effect of object plausibility at the noun and auxiliary positions in reduced complement sentences containing clausal-bias verbs. It introduces a stronger manipulation of object plausibility by selecting nouns which are not only plausible given a particular clausal-bias verb, but highly predictable (or schematic) as well. Given this stronger manipulation of object plausibility it is predicted that the schematic noun will be processed more rapidly than the nonschematic noun and that the normal preference of the clausal-bias verb for a sentential complement will be reversed in favor of a direct object. As a result of this reversal, the

subject will be garden-pathed at the auxiliary position and it will take significantly longer to process the auxiliary following a schematic noun than following a nonschematic noun.

Method.

Design. Two factors were manipulated in this experiment: a) position in the sentence following the verb (noun and auxiliary) and b) schematicity of the noun following the verb (schematic object vs. nonschematic object). All the test sentences in this experiment were reduced complement sentences containing clausal-bias verbs, although sentences containing NP-bias verbs were also included as fillers. As in Experiment 1, the dependent variable is the processing time per word in the input sentence and it is measured in terms of the time between button presses which cause the next word to appear.

Materials. The materials in this experiment include sentences containing the 16 clausal-bias verbs used in Experiment 1. For each clausal-bias verb, two reduced complement sentences were constructed, one containing a highly schematic object and one containing a nonschematic object. For example, for the verb *said*, the first sentence below contains a schematic object and the second sentence contains a nonschematic object:

1. The *child* (subject noun) ***said*** (clausal-bias verb) his *prayers* (schematic object) were few and far between
2. The *woman* (subject noun) ***said*** (clausal-bias verb) her *worries* (nonschematic object) were few and far between

For each pair of sentences, the subject noun (e.g., *child* and *woman*) and the object noun (e.g., *prayers* and *worries*) were matched for length and frequency based on the Kucera and Francis 1967) word frequency norms. The subject noun was selected to make a meaningful sentence in combination with the verb and complement. The noun following the verb was either a highly schematic possible object or a nonschematic possible object. Schematic objects were identified as the result of an informal (verbal) cloze procedure administered to several members of the laboratory. The complete set of sentences is provided in Appendix I. The resulting set of sentences differ from those used in Experiment 1 in that not all the sentences have a determiner following the verb (e.g., Sentence 3 below), words may occur between the determiner and the object noun (e.g., Sentence 4 below), and the position following the auxiliary was allowed to be the last word in the sentence (e.g., Sentence 5 below) and was itself an auxiliary in some sentences (e.g., Sentence 6 below):

3. The officer swore allegiance was required from every member
4. The explorer discovered the *new* world was very large
5. The criminals denied the charge was *valid*
6. The jury learned the truth should *be* thrown out.

Relaxing the structural requirements at positions other than the noun and auxiliary following the main verb facilitated the construction of sentences containing a strong

manipulation of object schematicity, while at the same time retaining the sentence structure for the two positions of interest.

The remainder of the materials for this experiment were the same as those used in Experiment 1 (including the sixteen sentences containing NP-bias verbs).

Procedure. This experiment used the same procedure as the first experiment.

Subjects. Sixteen students at New Mexico State University participated as subjects in the experiment. They had normal or corrected to normal vision and were native speakers of English. They received experimental credit for participating in the experiment.

Results.

The analysis of the data differ from that of the first experiment in the following ways: (a) the data for all test sentences were analyzed regardless of whether or not the subject said the sentence was grammatical, and (b) the data are only analyzed at the noun and first auxiliary position following the main verb. With regard to the first difference, including the subject determined ungrammatical test sentence data increases the number of data points available in each cell. Since subjects typically determined test sentences to be ungrammatical after seeing the entire sentence, inclusion of the data for such sentences seems reasonable. With regard to the second difference, the variable structure of the test sentences at positions other than the noun and auxiliary following the main verb (some sentences even lacked a determiner), and the lesser importance of these positions, led to their exclusion from the analysis.

A single ANOVA (subjects analysis) which manipulated position (noun vs. auxiliary) and object schematicity (schematic vs. nonschematic) was performed. Object schematicity and position were treated as within-subjects variables. A second ANOVA (items analysis) was also performed. Mean response times at the noun and auxiliary positions are shown in Figure 4 (subjects analysis). Based on the analysis of variance, there is a significant interaction of schematicity and position (subjects analysis: $F(1,15) = 4.785$, $p < .05$; items analysis: $F(1,15) = 6.764$, $p < .025$), with schematic objects being processed more rapidly at the noun position and nonschematic objects being processed more rapidly at the auxiliary position. Further, at the noun position, schematic objects (601 ms) are processed 155 ms faster than nonschematic objects (757 ms). This difference is significant using a matched t-test (subjects analysis: $t(15) = 2.607$, $p < .01$; items analysis: $t(15) = 3.363$, $p < .01$). At the auxiliary position, there is a 107 ms difference between schematic (640 ms) and nonschematic (533 ms) objects in the reverse direction with schematic objects being processed more slowly than nonschematic objects. This difference is also significant using a matched t-test (subjects analysis: $t(15) = 2.412$, $p < .025$; items analysis: $t(15) = 3.254$, $p < .01$).

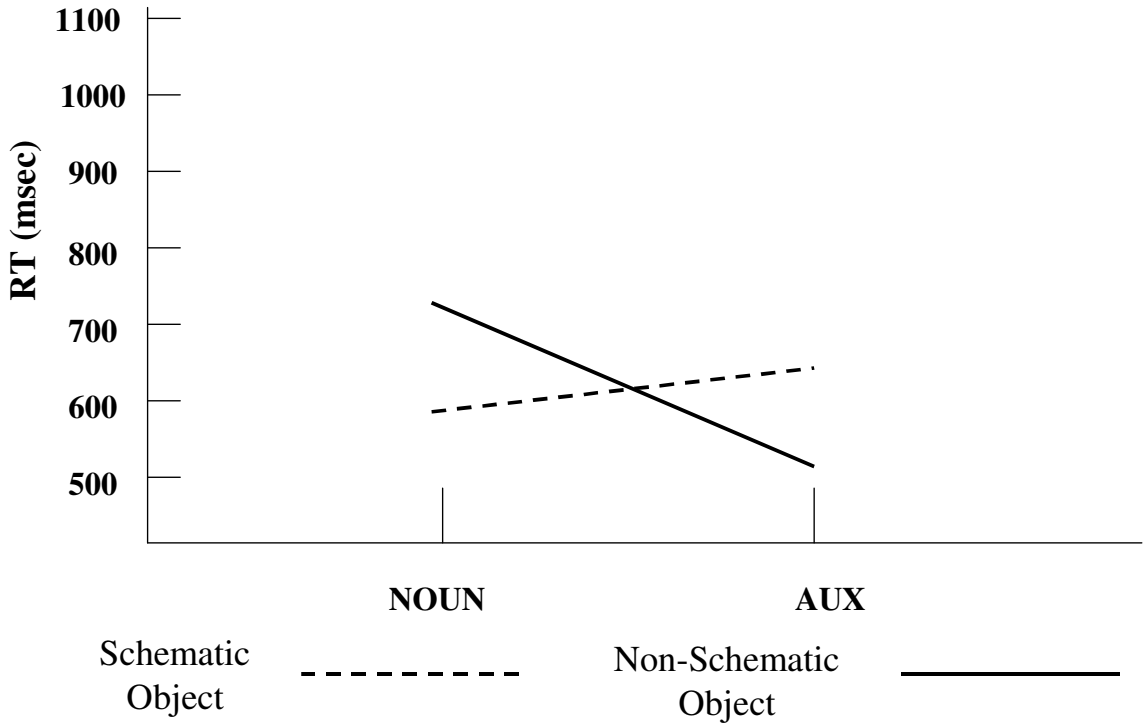

Figure 4: Schematic vs. Non-Schematic Object – Clausal Bias Verbs

Discussion.

The results of this experiment show a robust effect of object schematicity in reduced complement sentences containing clausal-bias verbs. Schematic nouns following the main verb are processed significantly more rapidly than nonschematic nouns. In terms of PM, this results from the availability of a concrete schema corresponding to the verb and schematic object which has preference over the more abstract relational schemas and which facilitates processing. When no concrete schema is available, the processing mechanism must rely on the more general relational schemas which are available and processing will be slower relative to the concrete schema case. At the auxiliary, processing is significantly slower following the schematic noun. The selection of the concrete schema overrides the normal clausal-bias of the verb leading to the analysis of the noun as the object of the verb. However, when it turns out that the schematic noun is actually the subject of an embedded clause, the subject is garden-pathed and forced to reinterpret the sentence, selecting the clausal interpretation after all.

On the other hand, the degree of garden-pathing is not nearly as large as was the case for reduced complement sentences containing NP-bias verbs with either a plausible or implausible object. Apparently, the preferences of clausal-bias verbs for either specific schematic objects or sentential complements are not as firmly entrenched as are the preferences of NP-bias verbs for a direct object. Also, the preference of the clausal-bias verb to take a sentential complement is likely to facilitate the processing of such a complement relative to an NP-bias verb, even when that preference is temporarily

overridden by a structurally different preference for a specific lexical item. That is, structurally competing preferences (the case for schematic objects in reduced complement sentences containing clausal-bias verbs) are likely to limit the degree of garden-pathing relative to structurally consistent preferences (the case for schematic objects in reduced complement sentences containing NP-bias verbs).

The results of this experiment demonstrate the influence of object schematicity (or plausibility) on the initial determination of sentence structure and argue against the position of Holmes et al. (1989), Tanenhaus et al. (1985), and the Weak Autonomy Model. By providing a stronger manipulation of object plausibility than that used in Holmes et al., it is possible to reverse the normal structural preference of clausal-bias verbs, resulting in a garden-path effect when the sentence in fact contains a clausal complement as opposed to a noun phrase object.

It may appear somewhat surprising to suggest that the occurrence of a specific lexical item can reverse the normal preference of a clausal-bias verb and still be processed more rapidly than a nonschematic lexical item. However, since this reversal only involves a structural preference concerning the subsequent input and not the structural representation of the preceding input, such a reversal does not require the deconstruction of the current representation and is not likely to consume large amounts of processing resources. Further, the predictability of the schematic object is likely to facilitate processing. In this experiment, the net result of the influence of these two factors was facilitory. While this experiment did not contain any NP-bias verbs, since the preference of such verbs for a direct object is consistent with the occurrence of a plausible or schematic object, we might expect the processing of plausible objects in reduced complement sentences containing NP-bias verbs to be more rapid than the processing of plausible objects in reduced complement sentences containing clausal-bias verbs, where the verb argument preference is inconsistent with the occurrence of a plausible or schematic object. In Experiment 1 of this study, plausible objects following NP-bias verbs in reduced complement sentences were processed 77 ms faster than plausible objects following clausal-bias verbs in reduced complement sentences. This value was not tested for significance since the effect of object plausibility was tested within verb type.

The rapid processing of schematic objects in this experiment bears a resemblance to the results of numerous studies of metaphor and idiomaticity (e.g. Gibbs, 1989, 1986, 1984, 1980; Glucksberg, Gildea & Bookin, 1982; Ortony, Schallert, Reynolds & Antos, 1978), which show that idiomatic or metaphorically entrenched sentences can be comprehended more rapidly in their idiomatic or metaphorical interpretation than in their literal interpretation, despite the fact that many models of metaphor and idiom comprehension assume a literal first interpretaton (e.g., Dascal, 1987; Fass, 1988; Searle, 1979). For example, Ortony et al. (1978, p. 465) state,

> It was found that the comprehension of phrases receiving an idiomatic interpretation took no longer than the comprehension of those same phrases when given a literal interpretation, and there was some evidence that idiomatic interpretations were consistently faster.

PM assumes that subjects have available in memory a large repertoire of schemas corresponding to frequently occurring expressions and phrases and that the availability of these schemas facilitates the processing of input text to which they apply. Idioms are an interesting case because their literal interpretation typically differs in meaning from the actual meaning of the idiom. In general, this need not be the case. The fact that the compositional interpretation of the elements of a schema may coincide with the gestalt interpretation of the schema as a whole does not preclude the existence of such schemas. It just makes them more difficult to identify. Understanding an idiom **requires** the existence of a schema for its interpretation. Understanding a frequently occurring expression whose meaning can be compositionally determined may or may not involve the application of a schema. However, since schemas are needed for the recognition and interpretation of idiomatic expressions in any case, and actually make it possible to interpret idiomatic expressions more rapidly than literal expressions, they are likely to be available as well for the interpretation of frequently occurring expressions more generally. The alternative is to suggest that we only construct such schemas when the interpretation of the expression as a whole differs from the compositional interpretation of its parts. But while the meaning of frequently occurring expressions may be determined compositionally, there are likely to be several possible interpretations given the general ambiguity of words, and schemas provide the additional advantage of rapidly selecting out a particular interpretation from among the possible interpretations.

General Discussion

From the perspective of PM, the Strong Autonomy Model and the Autonomy of Syntax Principle on which it is based make very little sense. The Strong Autonomy Model suggests that as each lexical item is processed and recognized, the processing mechanism initially extracts only the part of speech of the lexical item, ignoring all other information about the lexical item. This part of speech information is then used in the construction of syntactic representations which provide the basis for semantic interpretation. Essentially then, semantically laden lexical items feed into a syntactic analysis module which produces syntactic structures which are subsequently checked for semantic coherence. A major part of the check for semantic coherence involves consideration of the meaning of the individual lexical items. Thus, semantic information which is available at the time the lexical item is first processed is ignored until a structural representation is constructed. Once the structural representation is constructed, this semantic information is then used to judge the validity of the structural representation and if it is not valid the syntactic analyzer produces another structural representation which is subsequently tested for validity. This process continues until a structural representation is produced which is semantically valid. In effect, the syntactic analysis module is squeezed in between a processing level at which lexical items are initially processed and a level at which semantic information derived from lexical items is applied. If such semantic information is available at the time the lexical item is initially processed, why isn't it used to guide the syntactic analyzer?

Anyone who has tried to program a reasonably sized (non-toy) syntactic analyzer knows that the structure of English is extremely ambiguous. Even for simple sentences,

there are a multitude of possible syntactic structures. Further, there are even more partial structures which may be considered during the processing of a sentence, but which turn out not to be valid for the sentence as a whole. Moreover, the structural ambiguity of the syntactic analyzer explodes as the scope is expanded. Indeed, English is far more structurally ambiguous than Frazier seems to assume. As a simple example of that structural ambiguity, consider the fact that most verbs can be used as nouns and most nouns can be used as adjectives. Once a syntactic analyzer is extended to allow for such alternative uses, it is fair game as to what sort of structure will be returned during syntactic analysis (without some sort of semantic or lexical control). For example, if the syntactic analyzer is looking for a noun, and comes across a word which is almost always used as a verb, but which can be used a noun, then the analyzer will assume the word is a noun, despite the fact that this word is almost never used as a noun. Frazier's principles of minimal attachment and late closure have nothing to say about these forms of structural ambiguity, rather, they assume the extraction of the correct part of speech of the lexical item in the sentence being analyzed. Not only is the structural analysis of a sentence far more unconstrained than Frazier assumes, but if semantic and lexical factors are not allowed to influence the course of reanalysis after an initial syntactic structure turns out to be invalid, then there is little chance of that reanalysis returning a valid structure. Once again, anyone who has built a sizeable syntactic analysis program knows the frustration of seeing the program go down the wrong path, returning semantically invalid structure after semantically invalid structure (or failing to find a valid syntactic structure and backtracking only to go down another wrong path), before finally returning the semantically and syntactically valid structure. Frazier (1989) does appear to allow semantic factors to influence the course of reanalysis. But in so doing she essentially abrogates the notion of an autonomous syntactic module. If semantic factors can influence the course of reanalysis, why shouldn't they influence the course of the initial syntactic analysis as well?

The Strong Autonomy Model requires the subsequent semantic process to determine the validity of the structure provided by the syntactic analyzer. However, it is quite well known that a semantic interpretation can be constructed for almost any syntactic representation given an appropriate context or enough creativity on the part of the individual constructing the semantic interpretation. On further consideration, many of the semantically "invalid" structures returned by a syntactic analysis program turn out to be interpretable, although such interpretations tend to be highly dispreferred. Hence, the whole notion of semantic validity or interpretability is called into question. For example, consider the sentences

The ham sandwich is sitting at the third table

and

The car drinks gasoline.

Both of these sentences are semantically anomalous in their literal interpretation. However, the first sentence is interpretable as a metonymy and the second sentence is interpretable as a metaphor. Are we to assume that the preferred structural representation

for these sentences are initially determined to be semantically invalid, only to be reconsidered after all other possible structural options have been considered and found wanting as well? If not, then what distinguishes semantically valid from semantically invalid structures?

In sum, the basic problem of the Strong Autonomy Model is that the syntactic analyzer is far too unconstrained. Given the structural ambiguity of English, it is likely to return highly unusual structures far too often and it is not clear that the semantic interpreter will be able to rule such structures invalid.

Given the highly unconstrained nature of the syntactic analyzer, syntactic structures will have to be checked for semantic plausibility at very low levels of structural analysis in order to avoid making mistaken structural analyses (assuming this can even be done). Indeed, in a recent defense of the Strong Autonomy Model, Frazier (1990) acknowledges the influence of semantic factors as filters of structures below the phrasal level. Drawing from Jackendoff's (1977) exposition of X-Bar Theory which consists of the following phrasal levels: X''' (the maximal projection or phrasal level, and the level below which specifiers are represented), X'' (the level below which phrase internal modifiers are represented), X' (the level below which phrasal heads and internal arguments are represented), and X (the level at which part of speech information about the phrasal head is represented); she argues that semantic factors filter structures down to the level at which modifiers are attached. Further, she argues that given the weak structural preferences of modifiers at this level of representation, the structural principles of minimal attachment and late closure are only tentatively applied and the resulting structures are rapidly adjusted during subsequent filtering by semantic information (if necessary). At this level, her model is (nearly) indistinguishable from an Interactive Model. This is no coincidence, since she is trying to account for the results of several experiments by Taraban and McClelland (1988) which demonstrate the highly interactive influence of semantic information on the attachment of prepositional phrase modifiers. In allowing for the influence of semantic factors down to a sub-phrasal level, Frazier is adopting a fairly strong form of what Steedman (1989, pp. 487-488) calls the weak version of the **interaction** hypothesis:

> According to this version, syntax autonomously 'proposes' analyses, whereas semantics and context merely 'dispose' among the alternatives that it offers. The only interaction that is allowed is that interpretative processes may deliver judgment on the contextual appropriateness of the alternatives that are proposed by syntax, causing it to abandon some and continue with others.

Of course, as argued above, it is not adequate for semantics to merely "dispose" of alternatives given the highly unconstrained nature of the syntactic analyzer, and Frazier's position is even more interactive than is suggested by Steedman's weak version of interaction.

In defending the Strong Autonomy Model, Frazier (1990) is responding to a study by Taraban and McClelland (1988), initially reported in McClelland (1987), which showed that Rayner, Carlson, and Frazier (1983) had confounded semantic plausibility with minimal attachment in several experiments aimed at testing the validity of this principle.

In response, Frazier concedes the need to consider semantic factors early on in the determination of modifier attachment (Frazier's X'' level), but vigorously defends the principles of minimal attachment and late closure for the determination of argument structure (Frazier's X' level). However, the results of this study show that semantic factors, and in particular, the schematicity of possible objects, can influence the initial determination of argument structure as well. It may be that the studies of the influence of verb argument preferences on the initial determination of structure which were conducted by Frazier and colleagues, involve a similar confounding of semantic factors with these syntactic principles. For example, Pollatsek and Rayner (1990) provide the following example of a sentence containing a verb whose most typical use is intransitive, in arguing that minimal attachment and late closure apply despite the preference of the verb to be used intransitively:

Even though Jay usually jogs a mile seems very long to him.

In reading this sentence, the subject typically delays near the word *seems*, suggesting that the noun phrase *a mile* has been inappropriately treated as the direct object of the verb *jogs* in accordance with the principles of minimal attachment and late closure and despite the preference of the verb to be used intransitively. However, *jogs a mile* is a reasonably schematic unit whose specific preferences are likely to override the more general preference of the verb *jog* to be used intransitively. Thus, it is not the minimal attachment or late closure principle which is at work here, but the specific lexical preference of the verb *jogs* for the occurrence of a noun phrase object describing a distance (in miles). The occurrence of the adverb *usually* in this sentence may further contribute to the preference of the verb *jogs* for the occurrence of such a schematic object. In sum, based on (a) the apparent confounding of semantic plausibility with the principles of minimal attachment and late closure in experiments by Frazier and her colleagues, and (b) the results of this study, it is concluded that lexical factors exert an influence on the initial determination of structure down to the level at which argument structure is represented (Frazier's X' level).

Finally, preferences for specific lexical items may also be important in the determination of the part of speech of those lexical items (Frazier's X level). For example, consider the collocation

keynote address

If, during the processing of the lexical item *keynote* the syntactic analyzer extracts only its part of speech, then when it next processes the lexical item *address* this is the only information which will be available. The lexical item *address* is syntactically ambiguous having both a noun and verb form. If the syntactic analyzer had available information about the frequent association between the lexical item *keynote* and the noun form of the lexical item *address*, the syntactic analyzer could select the noun form of *address* and processing would be facilitated. Without access to this information, the syntactic analyzer can only make use of the more general preference of the word *address* to be used as a noun or verb in deciding what part of speech to use. But even in this latter case, a lexical preference is involved. If the part of speech preferences of specific lexical items were not

considered, the syntactic analyzer would frequently wind up forcing dispreferred (but possible) parts of speech on lexical items in pursuit of some particular rule of grammar which called for such a part of speech and in ignorance of the preference of the lexical item itself. Even if we allow the part of speech preferences of lexical items to determine the part of speech rather than rules of grammar (i.e. an implication of the lexical hypothesis), these preferences will not always hold. This is particularly true of words which can be used in a variety of parts of speech (e.g. the word *that*) and which have only weak preferences. On the other hand, the part of speech preferences of the individual words in collocations like *keynote address* are likely to be very strong and unlikely to fail to obtain (and if they do fail to obtain substantial disruption of the processing mechanism is likely to result). Given the immediate utility of such information for the initial determination of part of speech (Frazier's X level), it is difficult to see why it should be ignored by the syntactic analyzer.

In sum, there is support for the influence of lexical factors other than information about part of speech in the initial determination of structure at all the phrasal levels of representation considered by Frazier (1990). From a processing perspective, this effectively means that the influence of lexical factors other than the part of speech of the lexical item will need to be considered after the processing of each lexical item. Even if the influence of these additional lexical factors occurs in some filtering process, there is little basis for a distinction between a Strong Autonomy Model which allows for the influence of such factors following the processing of each lexical item and a fully Interactive Model.

In the Strong Autonomy Model, the influence of lexical information other than information about the part of speech of the lexical item on the initial determination of structure is excluded. However, some researchers who ascribe to the Autonomy of Syntax principle (e.g. Forster, 1989) do allow for such lexical influences, arguing that since they occur in the lexicon which is theoretically prior to the syntactic module, they do not violate the autonomy assumption. Indeed, the Strong Autonomy Model is hardly tenable given the large body of evidence demonstrating such lexical influences (beginning, perhaps with the semantic priming studies of Meyer and Schvaneveldt, 1971, and Schvaneveldt and Meyer, 1973). But, this further weakening of the autonomy assumption allows for the influence of any number of lexically realized semantic factors on the initial determination of structure and makes it even more difficult to distinguish autonomous from interactive models. For example, I need only note that verb argument preferences are assumed to be in the lexicon in PM. Thus, this information should be available to the syntactic analyzer and does not violate the weak autonomy assumption. In fact, this is the basis of the Weak Autonomy Model. Indeed, any information whatsoever which is stored in the lexicon can be used by the syntactic analyzer without violating the weak autonomy assumption. The debate then shifts to a consideration of what linguistic (and nonlinguistic) information is allowed in the lexicon. PM assumes that most knowledge of language is lexicalized. In this sense, PM complies with the weak autonomy position, although PM is better described as an Interactive (or Unified) Model. It's just that most knowledge of language is available at the lowest level of representation (lexical level) and is therefore available to all higher levels of representation (including any syntactic level that might exist).

The preceding discussion suggests that it is becoming increasingly difficult to distinguish interactive from autonomous models. Actually, some of the purported differences are little more than terminological. For example, Transformational grammar (Chomsky, 1957, 1965), on which Frazier's model of language processing is based, includes the use of selectional restrictions like *animate, inanimate, concrete, abstract*, etc., but considers these restrictions to be syntactic in nature, and Government and Binding Theory (Chomsky, 1981) includes what are called theta roles like *agent*, *patient* and *theme*, which are important to the determination of argument structure, but again defines them in purely syntactic terms (e.g., Wilkins, 1988). Both of these theories adhere to the Autonomy of Syntax hypothesis which focuses on the study of syntactic representations as distinct from representations of meaning. On the other hand, researchers working on semantically based models of language representation and process often make use of selectional restrictions and thematic roles, but define them semantically rather than syntactically. For example, Allan (1986, p. 263) states

> We…include the information supposedly carried by the syntactic 'inherent features' of *Aspects* type transformational grammars within the semantic component of the lexicon entry, seeing no reason to copy this information as part of the syntactic component of the entry.

Further, Somers (1990) criticizes the description of thematic roles in purely syntactic terms. In a similar vein, researchers who allow verb argument preferences to influence the immediate course of the syntactic processor can retain the Autonomy of Syntax hypothesis by arguing that such preferences are syntactically encoded in the lexicon. This appears to be Ford's position (Ford, Bresnan & Kaplan, 1982; Ford, 1986). In PM, verb argument preferences are based on the relational status of the verb, which is an aspect of the meaning of the verb. For example, propositional attitude verbs, by their very nature, establish a relation between an entity (object argument) and a proposition (propositional argument). To argue that such argument preferences are purely syntactic in nature is, first, to ignore the close association between meaning and form, and, second, to argue that what appear to be semantically laden terms are being used in a purely syntactic manner.

The results of Experiments 1 and 2 above support Interactive Models of language processing and argue against the Strong and Weak Autonomy Models. However, in a recent article, Ferreira and Henderson (1990) argue that the cumulative self-paced reading task is not valid for studying reading. They claim that subjects will tend to continue pressing the button to display the next word until the entire sentence has been presented and then proceed to read the sentence at their leisure. Indeed, subjects in the above experiments did tend to wait until the end of the sentence to make grammaticality judgments. However, the RTs for each word suggest that they were not waiting until the end of the sentence to read the sentence at their leisure. If they were, the result should have been an absence of effects. On the other hand, in an experiment using this paradigm, Ferreira and Henderson failed to obtain any significant effects despite the fact that they got significant effects with the same stimuli using eye monitoring equipment in a self-paced reading task. Based on this result they make the strong claim that "…the cumulative version of the self-paced paradigm is not appropriate for studying on-line

parsing" (ibid, p. 555). Unfortunately, their argument fails to explain why significant effects **were** found in the present study, and in previous studies by Holmes (1987; Holmes et al., 1989), using just this paradigm. By simply instructing the subject to try to determine the grammaticality or meaningfulness of the input sentence after the presentation of each new word, it is possible to couple button pressing with attentional focus and overcome the objections of Ferreira and Henderson. The strength of their claim is somewhat surprising given its basis in a null result and in its failure to consider that other researchers have in fact obtained significant effects using this paradigm.

Of course asking subjects to make a grammaticality judgment at each word in a sentence distances the experimental method from normal reading behavior. An alternative experimental method presents words one at a time, noncumulatively, with subjects being asked to answer a question at the end of the sentence rather than make a grammaticality judgment after each word. This method has been used by Holmes et al. (1989), Experiment 3, and Taraban and McClelland (1988, 1990). The basic results for this method are consistent with the cumulative presentation method, except that the effects tend to be delayed one or two words. Using this method in their Experiment 2, Ferreira and Henderson (1990) obtain verb bias effects at what they call the "post-disambiguating region". They argue that the occurrence of the effect of verb bias in the post-disambiguating region supports the notion that the verb bias effects occur during reanalysis and not during the initial determination of structure. This position is consistent with Frazier's Strong Autonomy Model in which semantic and contextual information is allowed to influence the course of processing as soon as the syntactic analysis process breaks down. From the strong autonomy perspective, the delayed occurrence of such effect reflects the influence of verb argument preferences on reanalysis and not on the initial determination of structure. However, from the interactive and weak autonomy perspectives, verb argument preferences affect the immediate course of processing, but the appearance of such effects is delayed in the noncumulative self-paced reading task.

In terms of experimental method, it is certainly the case that the use of an eye movement monitor to measure reading times has ecological advantages over the cumulative and noncumulative self-paced reading task which uses a button box to record reading times. However, use of the eye movement monitor has its own set of problems. For example, Ferreira and Henderson (1990, p. 558) measured first gaze durations rather than the more meaningful mean gaze durations in their Experiment 1, noting that for mean gaze durations "the pattern of data was similar to that found with first fixation duration but was not statistically reliable." However, O'Regan and Levy-Schoen (1987, p. 376-377) state that "we are…convinced that the factors affecting first-fixation duration, in the case when two fixations occur, are not related to lexical processing but to visuomotor control." The rapidity with which eye movements are programmed provides support for their position. Such movement decisions frequently occur within a time frame which is too short for lexical processing to have been completed. Another difficulty with the eye movement monitoring method has to do with the fact that subjects tend not to fixate on short function words. They apparently pick up enough information in the parafovea to process such high frequency, short length words without fixating on them. Thus, the time spent fixating on any given word is not a pure measure of the processing time for that word. Indeed, in the Ferreira and Henderson study (1990, p. 558) they note that

> …there was some tendency for the effect of the disambiguating word to appear during the fixation on the prior (ambiguous) word in the gaze duration data, presumably because attention was sometimes directed toward the disambiguating word during additional fixations on the ambiguous word.

This is just the sort of distancing between the dependent variable and the actual variable of interest that they complain about in the cumulative and noncumulative versions of the self-paced reading task. Not only can the processing of subsequent words intrude on a given fixation, but the processing of the previous word can intrude on a subsequent fixation. This latter problem is not unique to the eye movement monitoring method. In general, the amount of time spent on a word (measured using either eye movement monitoring techniques or button presses) is at best an inaccurate measure of actual processing time for that word. The eye movement monitor method is no less immune to this 'reality' than is the cumulative self-paced reading task, as Pollatsek and Rayner (1990, p. 159) make clear in the following quote

> …the most obvious and important conclusion to be drawn from this chapter is that the eye-movement record needs to be interpreted with great caution. We are far from being able to use fixation times to derive estimates of lexical access times (or the times of any other component processes of reading).

Summary

In sum, assuming the validity of the cumulative self-paced reading task (tied to a grammaticality judgment at each word), the results of Experiments 1 and 2 support PM's Interactive Model of language processing and argue against both the Strong and Weak Autonomy Models. Subjects have available a large collection of schemas organized at multiple levels of abstraction for use in language comprehension. More specific and concrete schemas (reflecting object schematicity) have preference over more abstract schemas (reflecting verb argument preferences) and can override the preferences of abstract schemas, facilitating, rather than hindering, the processing mechanism. Schemas represent both structural and semantic information, precluding a clear distinction between syntax and semantics and resulting in a highly interactive model of language processing.

Appendix I

NP-Bias Verbs (Reduced Complement Sentences)

1. The reporter **saw** her friend/method was not succeeding.
2. The secretary **read** the article/fashion was already out of date.
3. The doctor **found** the label/fever had disappeared completely.
4. The lawyer **heard** the story/issue was about to be publicized.
5. The salesman **wrote** the letter/market would be easy to locate.
6. The counsellor **urged** the daughter/contrast should be given some attention.
7. The mechanic **warned** the driver/engine was going to cause trouble.
8. The traveller **judged** the contest/climate would be rather uninteresting.
9. The professor **taught** the language/distance should be described carefully.
10. The scientist **showed** the sample/travel was necessary for her project to succeed.
11. The dentist **expected** her visit/mouth was going to take a while.
12. The neighbor **answered** her request/tragedy was already known to everyone.
13. The mayor **recognized** the author/pocket was worn out.
14. The politician **repeated** the comment/journal was not to be published.
15. The tutor **understood** the concept/session was quite interesting.
16. The tenant **remembered** the reply/smoke had surpised him.

Clausal-Bias Verbs (Reduced Complement Sentences)

17. The lecturer **said** the phrase/pencil was not particularly useful.
18. The constable **knew** the teacher/traffic had already been busy.
19. The actress **swore** the oath/exit was completely unplanned.
20. The defense **argued** the point/order was quite detrimental to their case
21. The technician **proved** the theorem/battery should be thrown out.
22. The observer **forgot** the outcome/weekend would be so crucial.
23. The policeman **denied** the charge/summer was going to be troublesome.
24. The editor **claimed** the victory/library would be complete.
25. The candidate **doubted** his sincerity/champagne would be appreciated.
26. The referee **decided** the match/award was important to the player.
27. The critic **learned** the truth/trial was being distorted in the press.
28. The inspector **realized** the mistake/vehicle had already been detected.
29. The worker **confessed** his faults/brakes had been ignored.
30. The solicitor **believed** the witness/journey was not really worth bothering about.
31. The actor **explained** the decision/audience had been disappointing.
32. The tourist **discovered** the route/opera was extremely complicated.

Clausal Bias Verbs (Schematic and Nonschematic Objects)

1a. The child(213) **said** his prayers(12) were few and far between.
1b. The woman(224) **said** her worries(20) were few and far between.
2a. The gangster(2) **knew** the score(66) would be paid.
2b. The tightwad(2) **knew** the check(88) would be paid.
3a. The officer(101) **swore** allegiance(4) was required from every member.
3b. The manager(88) **swore** dilligence(3) was required from every member.
4a. The lawyer(43) **argued** the case(362) should be held somewhere else.
4b. The driver(49) **argued** the race(103) should be held somewhere else.
5a. The evidence(204) **proved** his innocence(28) was undeniable.
5b. The military(212) **proved** his sacrifice(38) was undeniable.
6a. The detective(52) never **forgot** a face(371) has many different virtues.
6b. The principal(92) never **forgot** a mind(325) has many different virtues.
7a. The criminal(24) **denied** the charge(122) was valid.
7b. The liberals(26) **denied** the market(155) was valid.
8a. The rebels(17) **claimed** responsibility(118) was important.
8b. The voters(20) **claimed** communication (67) was important.
9a. Mary didn't **doubt** his sincerity(13) was genuine.
9b. Mary didn't **doubt** his champagne(13) was genuine.
10a. The jury(67) **decided** the case(362) should be thrown out.
10b. The cook(47) **decided** the food(147) should be thrown out.
11a. The jury(67) **learned** the truth(126) would be hard to find.
11b. The king(88) **learned** the enemy(88) would be hard to find.
12a. The politician(13) **realized** his dream(64) was a lie.
12b. The commission(103) **realized** his claim(98) was a lie.
13a. The drunk(37) **confessed** his sins(16) were bad.
13b. The mayor(38) **confessed** his cops(17) were bad.
14a. Jimmy(11) **believed** the (fairy(4) tale(21))(1) was long.
14b. Jimmy(11) **believed** the hairy(5) tail(24) was long.
15a. The judge(77) **explained** his decision(119) was being delayed.
15b. The agent(44) **explained** his property(156) was being delayed.
16a. The explorer(4) **discovered** the new world(787) was very large.
16b. The lecturer(6) **discovered** the new class(207) was very large.

Bibliography

Allan, K. (1986). *Linguistic Meaning*. London: Routledge & Kegan Paul.

Boland, J. M. Tanenhaus, & S. Garnsey (1990). "Evidence for the Immediate Use of Verb Control Information in Sentence Processing." *Journal of Memory and Language*, 29, pp. 413-432.

Bresnan, J. (1978). "A Realistic Transformational Grammar." In *Linguistic Theory and Psychological Reality*. Edited by M. Halle, J. Bresnan & G. A. Miller. Cambridge, MA: The MIT Press.

Chomsky, N. (1981). *Lectures on Government and Binding*. Dordrecht-Holland: Foris.

Chomsky, N. (1965). *Aspects of the Theory of Syntax*. Cambridge, MA: The MIT Press.

Chomsky, N. (1957). *Syntactic Structures*. The Hague: Mouton.

Dahlgren, K. & J. McDowell (1986). "Using Commonsense Knowledge to Disambiguate Prepositional Phrase Modifiers." In *Proceedings of AAAI 1986*.

Dascal, M. (1987). "Defending Literal Meaning." *Cognitive Science*, 11, pp. 259-281.

Fass, D. (1988). *Collative Semantics.* Report No. MCCS-88-118. Memoranda in Computer and Cognitive Science, Computing Research Laboratory, New Mexico State University, Las Cruces, NM 88003.

Ferreira, F. & J. Henderson (1990). "Use of Verb Information in Syntactic Parsing: Evidence for Eye Movements and Word-by-Word Self-Paced Reading." *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, pp. 555-568.

Fodor, J. A. (1983). *Modularity of Mind*. Cambridge, MA: The MIT Press.

Fodor, J. A. (1981). *Representations*. Cambridge, MA: The MIT Press.

Fodor, J. A. (1975). *The Language of Thought*. NY: Crowell.

Ford, M. (1986). "A Computational Model of Human Parsing Processes." In *Advances in Cognitive Science 1*. Edited by N. Sharkey. Chichester, England: Ellis Horwood Limited.

Ford, M., J. Bresnan, & R. Kaplan (1982). "A Competence-Based Theory of Syntactic Closure." In *The Mental Representation of Grammatical Relations*. Edited by J. Bresnan. Cambridge, MA: The MIT Press.

Forster, K. (1989). "Basic Issues in Lexical Processing." In *Lexical Representation and Process*. Edited by W. Marslen-Wilson. Cambridge, MA: The MIT Press.

Forster, K. (1979). "Levels of processing and the structure of the language processor." In *Sentence Processing: Psycholinguistic Studies Presented to Merrill Garrett*. Edited by W. Cooper & E. Walker. Hillsdale, NJ: LEA.

Frazier, L, (1990). "Parsing modifiers: Special purpose routines in HSPM?" In *Comprehension Processes in Reading*. Edited by D. A. Balota, G. B. Flores d'Arcais & K. Rayner. Hillsdale, NJ: LEA.

Frazier, L. (1989). "Against Lexical Generation of Syntax." In *Lexical Representation and Process*. Edited by W. Marslen-Wilson. Cambridge, MA: The MIT Press.

Frazier, L. (1987). "Sentence Processing: a Tutorial Review." In *Attention and Performance XII*. Edited by M. Coltheart. Hillsdale, NJ: LEA.

Frazier, L. & J. D. Fodor (1978). "The sausage machine: a new two-stage parsing model." *Cognition*, 6, pp. 291-328.

Frazier, L. & K. Rayner (1982). "Making and Correcting Errors during Sentence Comprehension: Eye Movements in the Analysis of Structurally Ambiguous Sentences." *Cognitive Psychology*, 14, pp. 178-210.

Gibbs, R. (1989). "Understanding and Literal Meaning." *Cognitive Science*, 13, pp. 243-251.

Gibbs, R. (1986). "What makes some indirect speech acts conventional." *Journal of Memory and Language*, 25, pp. 181-196.

Gibbs, R. (1984). "Literal meaning and psychological theory." *Cognitive Science*, 8, pp. 275-304.

Gibbs, R. (1980). "Spilling the beans on understanding and memory for idioms in conversation." *Memory & Cognition*, 8, pp. 149-156.

Glucksberg, S., P. Gildea, & H. Bookin (1982). "On Understanding Nonliteral Speech: Can People Ignore Metaphors?" *Journal of Verbal Learning and Verbal Behavior*, 21, pp. 85-98.

Holmes, V. (1987). "Syntactic parsing: In search of the garden path." In *Attention and Performance XII*. Edited by M. Coltheart. Hillsdale, NJ: LEA.

Holmes, V., L. Stowe, & L. Cupples (1989). "Lexical Expectations in Parsing Complement-Verb Sentences." *Journal of Memory and Language*, 28, pp. 668-689.

Jackendoff, R. (1977) "X-Syntax: A study of phrase structure." *Linguistic Inquiry Monograph 2*. Cambridge, MA: The MIT Press.

Jensen, K. & J-L. Binot (1986). "Disambiguating Prepositional Phrase Attachment by Using On-Line Dictionary Definitions." Report RC 12148 (#54633), Computer Sciences Department, IBM Thomas J. Watson Research Center, Yorktown Heights, NY 10598.

Kucera, H., & H. Francis (1967). *A computational analysis of present-day American English.* Providence, RI: Brown University Press.

McClelland, J. (1987). "The Case for Interaction in Language Processing." In *Attention and Performance XII.* Edited by M. Coltheart. Hillsdale, NJ: LEA.

Marslen-Wilson, W., & L. Tyler (1987). "Against Modularity." In *Modularity in Knowledge Representation and Natural-Language Understanding*. Edited by J. Garfield. Cambridge, MA: The MIT Press.

Meyer, D., & R. Schvaneveldt (1971). "Facilitation in recognizing pairs of words: evidence of a dependence between retrieval operations." *Journal of Experimental Psychology*, 90, pp. 227-234.

Mitchell, D. (1987). "Lexical Guidance in Human Parsing: Locus and Processing Characteristics." In *Attention and Performance XII*. Edited by M. Coltheart. Hillsdale, NJ: LEA.

Mitchell, D., & V. Holmes (1985). "The role of specific information about the verb in parsing sentences with local structural ambiguity." *Journal of Memory and Language*, 24, pp. 542-559.

O'Regan, J, & A. Levy-Schoen (1987). "Eye-movement Strategy and Tactics in Word Recognition and Reading." In *Attention and Performance XII.* Edited by. M. Coltheart. Hillsdale, NJ: LEA.

Ortony, A., D. Schallert, R. Reynolds, & S. Antos (1978). "Interpreting Metaphors and Idioms: Some Effects of Context on Comprehension." *Journal of Verbal Learning and Verbal Behavior*, 17, pp. 465-477.

Pollatsek, A., & K. Rayner (1990). "Eye movements and lexical access in reading." In *Comprehension Processes in Reading*. Edited by D. Balota, G. F. d'Arcais & K. Rayner. Hillsdale, NJ: LEA.

Rayner, K. M. Carlson, & L. Frazier (1983). "The interaction of syntax and semantics during sentence processing: Eye movements in the analysis of semantically biased sentences." *Journal of Verbal Learning and Verbal Behavior*, 22, pp. 358-374.

Schubert, L. (1984). "On parsing preferences." In *Proceedings of COLING 1984*.

Schubert, L. (1986). "Are there preference trade-offs in attachment decisions." In *Proceedings of AAAI 1986*.

Schvaneveldt, R. & D. Meyer (1973). "Retrieval and Comparison Processes in Semantic Memory." In *Attention and Performance IV*. Edited by S. Kornblum. NY: Academic Press.

Searle, J. (1979). "Metaphor." In *Metaphor and Thought* pp. 92-123. Edited by A. Ortony. Cambridge, England: Cambridge University Press.

Somers, H. (1990). Brief note on *Syntax and Semantics 21: Thematic Relations.* Edited by W. Wilkins. In *Computational Linguistics*, Vol 16, pp. 124-5.

Steedman, M. (1989). "Grammar, Interpretation, and Processing from the Lexicon." In *Lexical Representation and Process.* Edited by W. Marslen-Wilson. Cambridge, MA: The MIT Press.

Tanenhaus, M., & G. Carlson (1989). "Lexical Structure and Language Comprehension." In *Lexical Representation and Process.* Edited by W. Marslen-Wilson. Cambridge, MA: The MIT Press.

Tanenhaus, M., K. Stowe, & G. Carlson (1985). "Lexical expectations and pragmatics in parsing filler-gap constructions." In *Proceedings of the Seventh Annual Meeting of the Cognitive Science Association.*

Taraban, R., & J. McClelland (1990). "Parsing and Comprehension: A Multiple-Constraint View." In *Comprehension Processes in Reading*. Edited by D. Balota, G. F. d'Arcais & K. Rayner. Hillsdale, NJ: LEA.

Taraban, R., & J. McClelland (1988). "Constituent Attachment and Thematic Role Assignment in Sentence Processing: Influences of Content-Based Expectations." *Journal of Memory and Language*, 27, pp. 597-632.

Tyler, L. (1989). "The Role of Lexical Representation in Language Comprehension." In *Lexical Representation and Process.* Edited by W. Marslen-Wilson. Cambridge, MA: The MIT Press.

Wilkins, W. (ed.) (1988). *Syntax and Semantics 21: Thematic Relations.* NY: Academic Press.

Wilks, Y. (1972). *Grammar, Meaning and the Machine Analysis of Language*. London: Routledge & Kegan Paul.

Wilks, Y. (1975a). "Preference Semantics." In *Formal Semantics*. Edited by E. Keenan. NY: Cambridge University Press.

Wilks, Y. (1975b). "An Intelligent Analyzer and Understander of English." *Communications of the ACM,* 18, pp. 264-274.

Wilks, Y., X. Huang, & D. Fass (1985). "Syntax, Preference and Right Attachment." In *Proceedings of the 9th International Joint Conference on Artificial Intelligence (IJCAI-85).* Los Angeles, CA, pp. 779-784.