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Lexical access and syntactic processing of categorial ambiguities

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LEXICAL ACCESS AND SYNTACTIC PROCESSING OF CATEGORIAL AMBIGUITIES

by

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

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Abstract

LEXICAL ACCESS AND SYNTACTIC PROCESSING

OF CATEGORIAL AMBIGUITIES

by

Leslie Erica Roth

Advisor: Professor Martin Chodorow

Categorial ambiguity has important consequences for syntactic parsing, as part of speech determines which new nodes are created, when phrases are completed, and where they are attached in the phrase marker. In addition, lexical access of systematic categorially ambiguous words (SCA's) might differ from that of other types of ambiguity in that they might be stored under one lexical entry. This is contrasted with other forms of lexical ambiguity where the different meanings of a word are believed to be stored in separate lexical entries.

The present study investigated SCA's in syntactically ambiguous and disambiguated sentence contexts. Based on evidence by Frazier and Rayner (1987), Frazier (1990) has argued that categorial ambiguity must be resolved before parsing can proceed, necessitating the parser to delay processing when context cannot disambiguate category.

These experiments were devised to examine this claim. Experiment I included a Continuous Syntactic Decision (CSD) task, Rapid Serial Visual Presentation (RSVP), and a sentence completion task. The results suggest that the parser delays upon encountering Noun/Verb SCA's in ambiguous sentence contexts. It also appears from these data that

the parser exhibits a syntactic preference for a Determiner-Noun-Verb structure. Another major finding was that the parser initially expects the head noun to follow the determiner.

Experiment II corroborated the preference of the parser for Determiner-Noun-Verb. In addition, in Experiment IIa, the relative frequency of usage of the noun and verb forms predicted naming preference for SCA's presented without sentential context, whereas, in Experiment IIb, naming was controlled by the syntactic context of the sentence. Results were also consistent with a model of the lexicon in which SCA's are represented by a single entry.

Experiment III used a CSD task and sentences containing noun phrases of varying lengths. Results further supported the findings of Experiment I, that the parser anticipates a head noun directly succeeding a determiner, contrary to Frazier's claim that the head noun is assigned incidentally, as a by-product of parsing the noun phrase. The exception was when the word following the determiner was an Adjective/Noun SCA with a dominant adjective usage.

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CHAPTER ONE: INTRODUCTION

Lexical Access and Syntactic Processing of Categorial Ambiguities

Lexical ambiguity manifests itself quite often in natural language context. One estimate of syntactic ambiguity in the English language is that 42% of all words can serve multiple syntactic functions. The proportion is higher still for the 1000 most frequent words, at 72% (estimates from Carroll, 1970). The fact is that, even though a significant number of English words are ambiguous with respect to syntactic category, people hardly notice during ordinary comprehension because local syntactic cues, for the most part, determine the syntactically appropriate reading. Take, for example the lexically ambiguous word *tire* in (1) (from Seidenberg, Tanenhaus, Leiman and Bienkowski, 1982):

1a. The boy began to *tire*.

1b. The boy changed the *tire*.

The ambiguous word (or homograph) *tire* has two uses, each with a distinct meaning and syntactic category (part of speech) and is, thus, an instance of categorial ambiguity. The grammatical function of this homograph is fully determined by its syntactic environment. And, since each of its parts of speech has a separate meaning, this syntactic context also constrains the semantics, so that in (1a) it has the verb sense of "to become fatigued," whereas in (1b) it assumes the noun sense of "rubber wheel."

Some homographs have different meanings which are the same part of speech and, therefore, can only be disambiguated by virtue of their semantic context. In (2) below, the word *bank* is used in its two different noun meanings. (Note that this word also exists

in a verb form for each of its two meanings, and, so, is also a categorial ambiguity.) Which sense is meant in (2a and b) can be inferred from previous semantic information and general knowledge (e.g., it is less likely that one would get water at a financial institution).

2a. The boy got money at the *bank*. (from Swinney, 1979)

2b. The boy got water at the *bank*.

2c. The boy went to the *bank*.

However, (2c) poses another type of problem, that of global ambiguity. Here, there is no semantic cue within the sentence to resolve the meaning of *bank*. The reader is left to choose. On what basis is the selection made? In the absence of extrasentential context, perhaps the relative frequencies of the different senses of the word determine which will prevail. These frequencies are believed to be stored in the lexical entry for the word in the mental lexicon along with other of its lexical information, such as orthographic, phonological, syntactic, and semantic representations (Ryder and Walker, 1982). This internally stored knowledge is contrasted with the other external sources of information available to the Human Sentence Processing Mechanism (hereafter HSPM) such as semantic and syntactic context of the discourse, as illustrated above.

In some cases, there is a temporary ambiguity because the context needed to select a meaning for the ambiguity is not presented until later in the sentence. The sentences in (3) are temporarily structurally (syntactically) ambiguous until the word following *stops*:

(3a) After midnight, the bus *stops* at this corner.

(3b) After midnight, the bus *stops* are less frequent.

The verb form of *stops* is used in (3a) and the noun form in (3b). No previous sentential information (syntactic or semantic) disambiguates these sentences. Because this word exists in more than one syntactic category (noun or verb), it is also a case of categorial ambiguity. However, the noun and verb meanings are related. Therefore, this is an example of a systematic categorial ambiguity, as opposed to the unsystematic categorial ambiguity (*bank*) in (1).

An example of temporary structural ambiguity is demonstrated in (4) below (from Holmes, Stowe and Cupples, 1989):

(4a) *I suspected the boy.*

(4b) *I suspected the boy* was wrong.

It is not until the period is encountered in (4a) or the complement clause in (4b) that the subcategorization of the verb *suspected* is disambiguated. What is ambiguous here is whether the verb, as it is being used in this sentence, accepts a direct object or clausal complement structure (or, in other words, where the noun phrase attaches) which is subcategorization information about the part of speech. The lexicon is believed to list this type of information related to the subcategories of words (Ford, Bresnan and Kaplan, 1983; Clifton, Frazier and Connine, 1984) and it has been shown to play an important role in sentence processing.

In trying to understand how ambiguities like these are resolved in everyday language comprehension, a number of questions become evident (Ryder and Walker, 1982): How is the mental lexicon organized and what information is stored within lexical entries? By

what mechanism is this lexical information retrieved? How and when is the assignment of the syntactic and semantic function of each word of the sentence accomplished? The work presented here addresses most of these issues with regard to syntactic ambiguity. Questions related to semantic processing are not considered as the stimuli used contained only minimal semantic variation.

To begin answering some of these questions, it is necessary to devise experiments which will allow us to examine the different components of the HSPM that perform lexical and syntactic processing on sentences. Because the issues addressed here relate solely to the syntactic (and not semantic) aspect of sentence processing, it is important to use stimuli that do not vary in semantic content, such as those presented in (3) and (4) above. This has generally not been the case in previous research, as will be evident below.

The part of the HSPM that identifies words is the lexical processor. This subsystem works on the mental lexicon to retrieve lexical entries along with their associated information (e.g., meaning, part of speech, pronunciation). This is the process of lexical access. The mechanism that acts on the output from the lexical processor is the syntactic processor (or parser). The task of this subsystem is to assign syntactic structure to each word in the sentence. One question about the performance of the lexical processor is whether it can be affected either by the current state of the syntactic parser or by sentential context. This is the core of the controversy between selective and exhaustive lexical access. We will return to discuss the lexical access component of sentence comprehension and what influences it in a following section. But, first, we will examine

questions concerning the mechanisms involved in syntactic processing. Specifically, evidence has been presented which supports different modes of parsing strategies, the three major types being Serial, Parallel and Delay. Traditionally, it has been assumed that the parser implements only one single algorithm. However, the results of this body of research can also be interpreted as demonstrating that the parser will invoke the appropriate strategy for the circumstances. In other words, the parser can be seen as mutable, changing its mode of operation depending on the task at hand. We will next examine some of this research and see what evidence there is in the psycholinguistic literature for each of these strategies.

There are two concurrent and related themes that weave through this discussion. One is that of the Modularity controversy, which addresses the issue of the extent to which the different processors of the language comprehension system (phonological, lexical, syntactic, semantic) can propagate information and in which direction. The issue of modularity will be outlined more fully in our examination of lexical access below.

The other connected issue is the experimental question of what information is available to the parser at the time of the initial syntactic processing, the first parse. Does the parser initially incorporate lexical information or is it limited to the internal phrase-structure rules of the syntactic processing system in generating the first parse?

Without a doubt, verbs have been the major focus of this line of research because it is believed that the verb, which usually occurs early on in a sentence (in English), imparts crucial information about the structure of the sentence. In particular, there is much work on the parsing of different subcategorizations of verbs, which is evident in the following

section on Serial parsing strategies.

The next chapter reviews the experimental literature regarding the operation of the syntactic processor, specifically which types of strategies the parser employs and under which conditions.

CHAPTER TWO: Syntactic Processing

The Syntactic Processor: Serial, Parallel or Delay

There is evidence in the literature for each major type of parsing strategy and it should become clear over the course of this discussion that how the syntactic parser operates might very much depend on the nature of the information at hand. It is, therefore, more appropriate to consider this an investigation of which strategies apply to which parsing situations.

The Serial parser considers and commits itself to one syntactic structure at a time for an ambiguous word, backtracking and reanalyzing if incorrect. Evidence of backtracking (or garden-pathing) is usually taken as an indication of the application of a serial parsing strategy. Which alternate parse the syntactic processor prefers to follow first is a matter of debate between two main variants of the Serial strategy, that of Lexical Preference (LP) and Minimal Attachment (MA). Both of these approaches are preference-driven, either by a lexical (LP) or structural (MA) bias. We shall first appraise the evidence supporting the Lexical Preference principle of parsing.

The Lexical Preference Strategy of Serial Parsing

The LP strategy states that, when a syntactically ambiguous word presents itself, alternate syntactic structures of the word are ordered and chosen on the basis of their lexical preferences, or biases (i.e., the frequency of the different syntactic roles that the word can assume). This is considered a serial strategy because each alternative is tried

in turn until the correct parse is determined. The advantage of this strategy is that if the parser attempts the most likely option initially, chances are it will be correct and will not have to reanalyze. The biases can reflect major category (e.g., noun vs. verb) or subcategory (e.g., direct object vs. complement) usages.

Holmes (1984), in a further qualification of the LP position in his Verb Dominance principle, stated that some verbs can impart specific lexical information about the kinds of structures that are most likely to follow them. This lexical information can then be integrated by the parser in order to determine which alternative structural attachment would be most likely to follow the verb. In other words, lexical information about syntactic frames in which a specific verb can appear can cause the parser to anticipate these preferred structures which can then be used to guide the parse.

One of the first demonstrations of this principle was in an experiment by Ford, Bresnan and Kaplan (1982). They presented subjects with sentences in a questionnaire, such as those in (5) below, containing verbs that varied in their lexical biases and asked them to select a subsequent paraphrase that best corresponded to their first interpretation of the ambiguous sentence.

5a. The woman wanted the dress on the rack.

5b. The woman positioned the dress on the rack.

Subjects more often chose the interpretation consistent with the verb's lexical preference, its most frequent usage. They concluded that the order in which structural alternatives are tested is determined by their lexical preferences, with the most frequent syntactic usage first. However, Ford et al. used a post-sentential task which most likely

measured late stages of processing. Of course, people must eventually make use of lexical subcategory information to realize the most plausible sense of the sentence. The important question seems to be what factors can govern the *initial* syntactic parse. The following is a summary of the experiments that attempted to address this question by implementing various types of on-line processing measures in order to observe early stages of syntactic processing.

Mitchell and Holmes (1985) noted that all the previous experimental evidence suggestive of an immediate lexical influence on syntactic processing was indirect (Fodor and Garrett, 1968; Fodor, Bever and Garrett, 1974; Ford, et al., 1982), that is, it was collected using post-sentential, off-line tasks. They reasoned that in order to establish that any effect actually reflects initial parsing strategy, an on-line measure would have to be used and, so, they employed a phrase-by-phrase, subject-paced reading task with sentences such as the following:

6a. The historian suspected the manuscript of his book had been lost.

6b. The historian read the manuscript of his book had been lost.

In (6a), the subcategory bias of the verb, *suspect*, is for a complement completion. In (6b), the verb *read* has a bias toward taking a following direct object. (These biases were collected from norms obtained in a preliminary experiment.) These sentences are temporarily ambiguous at the start of the noun phrase (*the manuscript*) because they lack the optional complementizer *that*. The prediction is that subjects will garden-path in (6b) at the initiation of the test phrase ***had been lost*** because they will have parsed *the manuscript* as the direct object of the verb and will have to reanalyze the sentence.

Subjects would initially make the appropriate syntactic decision in (6a) following the lexical bias of the verb, and, thus, would not garden-path. They reported that subjects' times to read the test phrases were shorter when the sentence was resolved in the lexically preferred direction and therefore concluded that detailed lexical information can affect the course of syntactic processing.

In a second experiment these researchers addressed the question of whether their stimulus presentation method was too artificial, the stimuli being presented in a segmented fashion (phrase-by-phrase). Comparable results were obtained using the same stimuli in a whole sentence presentation.

A further experiment using the same stimuli sought to establish that their results were not caused by implausibility of the lexically nonpreferred versions of the sentences, but were indeed indicative of a strictly syntactic effect. In order to cue the parser to the correct parse, punctuation marks were added to the stimulus sentences. In addition, the complementizer *that* was inserted where appropriate and sentences were segmented in favor of the correct analysis. For three of the four verb types tested, the effects from the previous experiments dissipated, showing that the use of lexical preference information could be overridden by surface structure cues.

Mitchell and Holmes, therefore, summarized their results as evidence that the lexical representation of a verb contains decisive subcategory information that can be shared with the parser. The parser, in turn, can then use this information to disambiguate a following phrase in the initial stages of syntactic processing. Clifton, Frazier and Connine (1984) describe what form this lexical information would take within the lexical entry. This

material must specify the syntactic category of the word and also the categories of all the phrases which it is able to take as complements, perhaps in terms of frames that designate the complements' thematic roles, along with their relative frequencies.

The experimental motivation of Clifton, et al. was similar to that of Mitchell and Holmes. They wished to demonstrate that lexical subcategory information could be used early on in syntactic processing, independent of semantic and/or pragmatic (plausibility) factors. An automatically paced, noncumulative word-by-word method was used to present the stimulus sentences. Verbs with either transitive or intransitive preferences were included. An example set follows.

7a. The babysitter read the / story to the sick child.

7b. The babysitter sang the / story to the sick child.

7c. The babysitter read to / the sick child.

7d. The babysitter sang to / the sick child.

The word immediately following the verb (*the, to*) served to disambiguate the verbs subcategorization (transitive or intransitive) in the sentence. A lexical decision task was inserted at this junction (designated by the "/" in the above example stimuli), the reasoning being that this task would take longer in cases in which the subject needed to recompute the current parse construction.

In versions (7a) and (7d) above, the verb resolution is in concordance with the lexical subcategorization preference. However, in (b) and (c), the verb preference is at odds with the sentence continuation after the verb (incongruous condition). That is, in (7c), the introduction of a preposition following a transitive preference verb would necessitate the

removal of a predicted noun phrase, which the parser might have anticipated based on the lexical preference. This extra processing demand would diminish resources causing difficulty on the secondary lexical decision task.

The results confirmed the LP theory; lexical decision times were significantly longer for incongruous stimuli. In addition, Clifton, et al. pointed out that lexical information had an effect prior to semantic integration of the text, since the word following the verb conferred no semantic information about the complement, and therefore, the effect must have been a purely syntactic one.

Holmes, Stowe and Cupples (1989) again tested the theory of LP using NP-bias (direct-object bias) and clausal-bias (complement bias) verbs. All the stimulus sentences were clausal complement constructions, but each verb was placed both in a sentence with and without the complementizer *that* (8).

8a. The reporter saw (that) her friend was not succeeding.

8b. The reporter saw (that) her method was not succeeding.

8c. The candidate doubted (that) his sincerity would be appreciated.

8d. The candidate doubted (that) his champagne would be appreciated.

The example stimuli in (8a and b) are plausible and implausible versions of the NP-bias verb *saw*, whereas (8c and 8d) are for the complement-bias verb *doubted*. The prediction was that there would be increased processing for complement constructions without the complementizer present (reduced complements) compared to the versions with the complementizer, but only in the NP-bias sentences because the NP-bias would cause the initial parse to be the direct object construction. The sentences containing the clausal-bias

verbs would initially be parsed accordingly, and correctly so, with or without the complementizer present.

Holmes, et al. also noted that in a previous demonstration of LP (Mitchell and Holmes, 1985) the stimuli were confounded with plausibility. In (6a), above, there is an indication in the materials that the direct object construction is inappropriate since one cannot very well suspect a manuscript. It is possible that this alerted the parser to ignore the direct object parse as implausible. In the current stimuli, this variable was directly manipulated by including matching sentences as in the less plausible constructions (8b and d). This was to directly test whether pragmatic information was the cause of Mitchell and Holmes' (1985) previous results.

In their first experiment, which used a continuous syntactic decision (CSD) task with a cumulative display, they reported a substantial (403ms) advantage of complementizer over reduced complement sentences at the point of disambiguation, but only for the NP-bias condition. This implies that initially subjects incorrectly parsed the sentence in favor of the bias of the verb, as a direct object construction, and had to reanalyze upon reaching the complement clause.

However, a different pattern emerged for the clausal-bias stimuli. Here, the reduced complements took significantly longer to read than the complementizer forms by the beginning of the post-verbal noun phrase (*his* in 8c and d). The authors suggest that this might be a result of the subjects expecting an overt complementizer (*that*) as an indication of a clausal complement construction after the clausal-bias verb, although the complementizer is strictly optional. It appears that the subjects were not anticipating a

noun phrase, as in a direct object structure.

In addition, they report a difference of 110ms at the point of disambiguation (hereafter POD) for the clausal-bias verbs. This was significantly smaller than the difference at this point for the NP-bias verbs and was, therefore, considered to be an effect of different origin. Specifically, it was argued that this small effect was due to some proportion of subjects having deserted the original complement analysis at the post-verbal noun phrase in favor of a direct object parse only to be found wrong at the POD, necessitating a reinstatement of the complement clause form.

The only significant plausibility effect found was for the NP-bias verbs at the noun phrase. This was observed for both reduced and complementizer types. It is more apparent why this effect would hold for reduced forms - the bias would cause an initial direct object parse which would be realized as implausible upon encountering a semantically inappropriate noun. However, to explain the same result for the complementizer sentences, Holmes et al. made the argument that the bias effect must have been so strong as to override the presence of the complementizer, which should unambiguously signal a complement clause structure.

Because of concerns about the unnaturalness of the CSD task in Experiment 1, a second experiment was carried out using a subject-paced reading task with a cumulative display in which the subjects were sometimes asked to repeat the sentence. No effects of plausibility were found in this experiment, but the general findings for NP-bias and clausal-bias conditions were reproduced with the exception that the significant differences were found shifted one word to the right. This was attributed to the difference in tasks.

Yet a third experiment was used to test whether subjects could be more often persuaded to abandon the complement clause analysis in the case of reduced complement clausal-bias sentences, as was suggested in the first experiment. Holmes et al. reasoned that if they lengthened the distance between the verb and the POD, this might induce subjects to give up the complement construction and switch to a direct object parse. As before, a subject-paced reading task was employed but this time the subjects were required to answer a question at the end of the sentence. In addition, the display was sequential rather than cumulative.[1] The same materials were used but a longer version was constructed in addition to the short ones. An example of a long form is given in (9).

9. The lawyer heard (that) the story about the accident was not really true.

The results for the NP-bias verbs reconfirmed the hypothesis that lexical bias was indeed guiding the initial parse for both the long and short forms. Garden-pathing was found at the POD for the clausal-bias verbs only for the long reduced complement condition which the authors took as further proof that subjects were initially taking a complement analysis but were then abandoning it in the wake of the long intervening material.

The general conclusion drawn from these experiments was that if the lexicon has frequency information about what types of linguistic items can follow a verb, then the parser is in a position to anticipate the most likely continuation of the sentence, and in

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[1]The authors note that there are differential effects for these two display modes. For instance, only in the sequential mode does word frequency affect reading time. However, in the cumulative display mode, it is possible that subjects might be revealing the next word before they have completely accessed and integrated the previous word.

so doing will be garden-pathed on those occasions in which the sentence proceeds in a direction that is counter to its expectations.

Taken together the above collection of experiments appears convincing that the early stages of syntactic processing can, in fact, be guided by lexical information in the form of verb subcategory frequencies. However, another group of researchers possess a body of evidence that argues for a completely different serial parsing strategy, that of Minimal Attachment (MA).

The Minimal Attachment Strategy of Serial Parsing

The MA principle states that initially considered syntactic structures are constructed using only inherent phrase-structure rules which are context free (Frazier, 1987). In other words, all the information that is used o initially direct parsing is internal to the syntactic processing system. No external source of information is considered, either in the form of lexical knowledge or in the form of semantic or syntactic context, to complete the earliest parse. Application of these phrase-structure rules that govern parsing produces the simplest parse, that is, the construction that requires the computation of the minimum number of syntactic nodes given the current state and that is still consistent with the well-formedness rules of the grammar.

Like the LP theory, this principle is an efficient one in that it postulates that only one analysis at a time is considered and no material is left in memory unstructured. Nevertheless, it will also fail on occasion causing a reanalysis to occur.

Let us turn now to considering the evidence in favor of the serial strategy of MA.

Motivated by predictions of Frazier's (1978) model of MA, Frazier and Rayner (1982) tested constructions such as the following:

10a. Mary suspected the man from Calgary.

10b. Mary suspected the man had committed the crime.

Sentences such as these are considered temporarily ambiguous throughout the postverbal noun phrase (here, *the man*) as it is unclear whether this noun phrase acts as the direct object of the verb (as in 10a) or if it is the subject of a complement clause of the verb (as in 10b).

Frazier and Rayner speculated that subjects would initially parse these sentences as direct object types, which is the structurally preferred one as predicted by MA. Their eye movement data from a reading task bear this out, with eye fixation durations significantly longer for the (b) version at the POD (here, *had*). Because this word disambiguated the analysis towards the less preferred complement clause parse, the subjects had to reanalyze from the MA (direct object) syntactic structure they had created.

In 1983, Rayner, Carlson and Frazier again sought to establish that it is only structural preferences predicted by MA that guide the first pass of syntactic analysis by examining whether sentence-internal plausibility constraints could affect MA strategy. They assembled sentences such as below that contained pragmatic information in order to observe whether this would serve to disambiguate the subcategory of the verb.

11a. The florist sent the flowers was very pleased.

(reduced relative implausible)

11b. The performer sent the flowers was very pleased.

(reduced relative plausible)

11c. The performer who was sent the flowers was very pleased.

(unreduced plausible)

11d. The performer sent the flowers and was very pleased with herself.

(direct object implausible)

They reasoned that, by MA, the direct object reading should be computed for (11a, b, and d), with subsequent reanalysis necessary in the complement constructions (11a and b). However, if the syntactic processor can make use of pragmatic information early on, then (11b) is likely to be parsed as a complement clause structure because this encompasses the most plausible assignment of the postverbal noun phrase based on pragmatic information.

Rayner et al. reported results from a reading task in which eye movement data were collected. They found that, in support of MA, first pass (first fixation) reading times were greatest at the POD (verb following the noun phrase) for both the plausible and implausible readings of the reduced relative construction. This suggested that subjects were initially computing the structurally preferred simple direct object construction whether or not this analysis was the more plausible alternative parse. There was also no indication in the direct object implausible condition that subjects were being garden-pathed based on pragmatic information. They concluded that the first pass analysis is not affected by the relative plausibility of the two alternative analyses of an ambiguous string.

In a second experiment Rayner et al. found faster reading times for sentences in which the most plausible reading was the MA version of the sentence. Therefore,

pragmatic information does eventually have an influence on the final syntactic analysis, but this was hypothesized to be the work of a higher-level thematic processor, distinct from the syntactic processor which initially only computes the structurally preferred (MA) analysis. In this experiment, the source of pragmatic information is supralexical, that is, the knowledge about whether or not florists receive or send flowers would presumably not be available until a cognitive level beyond lexical.

In order, then, to make a more convincing argument that pragmatics is not initially used by the syntactic processor, Ferreira and Clifton (1986) further constrained the type of pragmatic information available in the sentence. They used verbs that require animate as opposed to inanimate agents. This is a grammatical restriction that is most likely stored in the lexical entry of the verb and, as such, might be considered lexically-based pragmatic information. They argued that this type of pragmatic information might be more likely to be available to the syntactic processor for initial parsing since it would be able to be accessed and communicated by the lexical processor. Take, as an example, (12).

12a. The evidence (that was) examined by the lawyer turned out to be unreliable. (inanimate)

12b. The defendant (that was) examined by the lawyer turned out to be unreliable. (animate)

Both the reduced readings go against MA predictions and as such should incur difficulty at the POD (the prepositional phrase *by the lawyer*). This misanalysis is not expected to be observed in the syntactically unambiguous unreduced versions of the sentences.

However, notice that in (12a) the subject, *evidence*, cannot be considered an agent of the verb because it is inanimate. This might effectively eliminate the ambiguity if the parser can avail itself of this information. If so, subjects should encounter no problems for this condition. However, in (12b) *defendant* can serve as the agent and so the ambiguity stands and subjects would be garden-pathed. If semantic information of this type cannot assist the parser in its initial analysis, then the information might still be able to be used to facilitate the necessary reanalysis upon encountering the disambiguating phrase.

Ferreira and Clifton reported that, compared with the unreduced versions, the reduced versions showed signs of processing difficulty (slower reading times) at the prepositional phrase (*by the lawyer*) which disambiguated the syntax. Therefore, the presence of disambiguating syntactic information in the form of the complementizer was sufficient to disambiguate the structure of these sentences indicating that subjects can make use of syntactic information in resolving this kind of ambiguity.

The fact that there was no interaction between reduction and animacy indicated that this factor could not block the incorrect MA construction in the reduced sentences. This suggests that animacy information was not used by the parser in initially structuring this type of material, even though it was available at the time that the parser had to categorize the main verb. Instead, subjects waited for subsequent syntactic material to disambiguate the parse.

These results further substantiate the claim that the syntactic processor can apply only internal phrase-structure rules to construct an initial parse and that it is, for all intents and

purposes, initially oblivious to extrasyntactic information, except for a word's major syntactic category.

In the previous experiment, Ferreira and Clifton examined whether pragmatic information interacts with the syntactic processor in the initial analysis and found no evidence in favor of this. Ferreira and Henderson (1990) extended this work by investigating the role of lexical information about syntactic properties in facilitating the initial parsing of temporarily ambiguous verbs. They used sentences such as the following in an eye-movement study:

13a. He wished (that) Pam needed a ride. (clausal bias)

13b. He forgot (that) Pam needed a ride. (MA bias)

All stimulus sentences were resolved in a complement clause construction. In (13a), they state (questionably) that the main verb *wished* unambiguously takes a complement clause. Although the verb *forgot* in (13b) may resolve in either a direct object or complement clause construction, it is biased toward the direct object analysis.

MA predicts that the noun phrases in (13a and b) will initially be parsed as direct objects (without the complementizer present), that being the structure that entails the least number of node additions to the current phrase marker, even though the verb in (13a) prohibits such an analysis. This is because the model does not allow the use of subcategorization information by the parser in the first pass analysis, but only in a later revision.

However, in cases such as above, where the verb is most likely to take a complement clause, it would seem beneficial for the parser to have access to lexical information that

could disambiguate the verb subcategory in order to effect the appropriate initial parse, thereby circumventing a costly reanalysis. Ferreira and Henderson termed this the Verb Guidance Hypothesis and their eye-movement experiment was designed to test whether lexical subcategorization information can override the application of MA rules. The Verb Guidance principle would predict that garden-pathing would be observed only for (13b) because subjects would initially parse the noun phrase as a direct object in agreement with subcategory information and would then, upon reaching the POD, have to reanalyze it as a clausal complement.

Their data show that, consistent with MA, first fixation times were longer in the disambiguating region in the sentences without a complementizer, regardless of verb subcategory bias. This means that subjects initially applied MA even in the case where the verb had no usage as such. The conclusion was that verb subcategorization bias (lexical information) could not override the application of MA rules.

Because there was a suggestion of a verb bias effect in the post-disambiguating region, Ferreira and Henderson conducted a second experiment, but used a subject-paced reading task. The results were similar to those obtained in the eye-movement task, with reading times in the disambiguating region longer when the complementizer was absent, and there was no interaction of presence of complementizer with verb bias. However, this interaction was found to be significant in the post-disambiguating region with clausal bias verbs taking less time than MA bias verbs when the complementizer was absent suggesting that verb bias can facilitate the reanalysis process. From Ferreira and Henderson's results, it appears that verb bias was not accessible in initial parsing, but that,

in a second pass analysis, verb bias was available to produce a faster recovery from the incorrect MA parse.

Similar effects have been found by Mitchell (1987) in a phrase-by-phrase, noncumulative, subject-paced reading task. Using sentences split into two consecutive phrases as indicated in (14), he obtained significantly longer reading times on the first phrase for unambiguous intransitive verbs (14b) compared to ambiguous (transitive/intransitive) verbs (14a).

14a. After the child had visited the doctor (1)
prescribed a course of injections. (2)

14b. After the child had sneezed the doctor (1)
prescribed a course of injections. (2)

However, for the second phrase, the effect was reversed with significantly longer reading times for the version with the transitive verbs.

From these data, Mitchell formulated a theory of two distinct stages in syntactic processing. In the first stage, a preliminary MA analysis is performed without the benefit of subcategory information, but which has access to major category information (e.g., noun/verb). The second stage, which attempts to confirm the first parse, is able to take advantage of lexical subcategory information.

Mitchell argued that the reason for the obtained pattern was that the ambiguous verb sentences received an initial direct object (MA) parse which agreed with a subsequent check of the verb subcategory information, confirming that the verb could be used in this way. However, the initial MA parse was found to be incorrect during the second phrase,

which necessitated a reanalysis and an increase in reading time in this region.

According to Mitchell's account, the noun phrase in the intransitive verb sentences was initially parsed as a direct object (MA) but a subsequent checking phase was able to reject this parse by recognizing that the verb was strictly intransitive. It then took longer to reanalyze the verb as intransitive, but, once this reanalysis had been carried out, the second phrase was read faster because it resolved in agreement with the verb subcategory assignment.

A recent experiment by Clifton, Speer and Abney (1991) has yielded support of this two-stage model of processing. They tested sentences that contained a prepositional phrase whose appropriate attachment site in the parse tree was determined by plausibility. For example, in (15a and b) below, the prepositional phrase (*in a wallet, in a hurry*) modifies (and, thus, attaches to) the preceding verb (*interest* and *expressed*, respectively), but it is only plausibly an argument relation of the verb in the former. Similarly, the prepositional phrase in (15c and d) modifies the preceding noun, but only in the former is it plausibly an argument of the noun.

15a. The saleswoman tried to interest the man in a wallet during the storewide sale.

15b. The man expressed his interest in a hurry during the storewide sale.

15c. The man expressed his interest in a wallet during the storewide sale.

15d. The saleswoman tried to interest the man in his fifties during the storewide sale.

Obligatory items (e.g., a transitive verb's direct object) are examples of arguments, and this depends on the argument structures listed in the lexical entry of the specific argument assigner (here, *interest*). Adjuncts, which are always optional, are not lexically

selected. In (15a), the prepositional phrase is considered an argument of the verb *interest*, whereas in (15b), the prepositional phrase is an adjunct of the verb *expressed*. Similarly, in (15c), *in a wallet* is an argument, while in (15d), *in his fifties* is an optional adjunct.

According to Abney (1989), this distinction is an important one and could be the source of the experimental results in support of the MA strategy. In the materials used in these experiments, many of the verb modifiers, in addition to being minimally attached to the verb, were also its arguments. Such sentences are typically compared to non-MA versions in which the same phrase modifies a noun, but serves only as an adjunct. Abney has put forth a variant of the LP theory in which the syntactic processor prefers argument attachments over adjunct attachments (a distinction grounded in lexical knowledge). Therefore, Abney's theory yields the same predictions as the MA theory for some types of constructions.

Coming back to the Clifton et al. experiment, they wished to put Abney's theory to the test against the MA principle. The experiment included verb attachment and noun attachment PP's that functioned either as arguments or adjuncts. In a subject-paced, noncumulative, phrase-by-phrase reading task, the results showed that reading times were faster through the prepositional phrase for the verb attachment constructions (as in 15a and b), but that argument structures were faster in the post-prepositional phrase region (15a and c). These results were replicated using an eye-movement reading task in a subsequent experiment.

The researchers concluded that MA is the first strategy that is applied in parsing, with argument vs. adjunct status affecting a second stage of processing. Therefore, category

information guides initial parsing, and specific lexical information (e.g., argument structure) is taken into account subsequently. Based on this, they have proposed a mixed model encompassing both phrase structure- (MA) and frame-driven (LP) components.

Recently, Gorrell (1989) has presented contradictory evidence that appears to show subcategory information being used early in processing.[2] In a reading task, a noun or preposition was presented for lexical decision after the presentation of a transitive or intransitive verb. The prediction was that if MA was operating initially, lexical decision times to nouns after both transitive and intransitive sentence types would be the same because the parser would be expecting a noun based on a transitive (MA) reading (based on Wright and Garrett's 1984 finding that syntactically appropriate targets produce faster reaction times than those which are inappropriate). However, if subcategory information is in initially available, then the parser would expect a noun only in the case of the transitive verb and lexical decision times for nouns would be faster there than for the intransitive verb use. Gorrell found that nouns did result in faster reaction times for the transitive condition. He concluded that the lexical processor must make available subcategory information to the syntactic processor and that, in addition, the syntactic processor can incorporate that information rather quickly.

It seems that the evidence now is in favor of the MA strategy. There are many

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[2]Gorrell considers Mitchell's (1987) two-stage theory to mean that the use of subcategory information is delayed until a second stage. It is not necessarily the case that the parser actively delays the use of this information. It might be that the syntactic processor begins constructing a parse as soon as it receives the first information from the lexical processor (which is presumably category information), but that subsequent subcategory information takes longer to access and transmit to the parser.

criticisms from both sides about the methodologies used. For example, stimuli have often been presented either with contrived line breaks, which can induce garden-pathing or with a cumulative display, which can cause subjects to delay processing until the end of the sequence. These issues may account for some of the discrepancies in the results obtained.

The Parallel Parsing Strategy

As mentioned previously, much of the parsing research has examined syntactic processing for evidence of some kind of serial strategy. However, based on different experimental results and reinterpretations of existing data (Foss, 1970; Lackner and Garrett, 1973; Chodorow, 1976; Kurtzman; 1985, Gorrell, 1987) there are those who contend that it is the Parallel strategy that is operating. Parallel models are distinct from serial models in that they construct multiple parses, one for each possible interpretation of the ambiguity, as opposed to one single preferred parse.

Kurtzman (1985), for one, has pointed out that some findings that are compatible with a serial MA model (that is, where the parser shows evidence of preference for the simplest syntactic parse) can also be explained by an ordered parallel model in which the parser computes multiple analyses and ranks them according to, for instance, either pragmatic, structural or lexical preferences. In particular, Kurtzman suggested that the eye-movement data of Frazier and Rayner (1982), in which the nonpreferred (non-MA) construction incurred some processing cost at the POD compared to the MA condition, could be attributed to the parser having to accept the less preferred analysis at the POD from among the ranked alternatives.

In support of the parallel model, Gorrell (1989) obtained results from an experiment in which lexical decision targets that were either syntactically appropriate or inappropriate were presented immediately before the POD (at the position indicated by the "/" in 16 below). The two types of ambiguities that were tested involved transitive/intransitive (direct-object/complement) verbs and simple past tense/passive participle verbs. A sample transitive/intransitive stimulus set follows in (16).

16a. It's obvious that Holmes saved the son of the banker / right away (unambiguous direct object)

16b. It's obvious that Holmes suspected the son of the banker / (right away I was guilty) (ambiguous)

16c. It's obvious that Holmes realized the son of the banker / was guilty (unambiguous complement)

Lexical decision targets were either verbs (e.g., *has*) or pronouns (e.g., *me*) with pronouns always resulting in ungrammatical continuations. Gorrell obtained significantly longer reaction times in the direct object, MA condition (e.g., 16a) than for either the ambiguous or the complement (16b and c) versions when the target was a verb. Note that a verb is a syntactically appropriate continuation in both (16b and c) but not in (16a). Gorrell reasoned that because syntactic priming was shown only for verbs which were structurally predicted by nonminimal attachment analyses this implied that the nonpreferred analysis had already been constructed (otherwise the verb could not have been primed), which is only predicted by a parallel parsing model.

Gorrell's data also suggest that there might not be any computational cost associated

with constructing multiple parses. He obtained (comparable) faster lexical decision times for both the ambiguous and unambiguous intransitive conditions. If it is assumed that in the ambiguous condition (16b) both parsing alternatives are constructed but that in the unambiguous complement condition (16c) only the appropriate (allowed) parse is built, it is tempting to conclude that there is no additional cost involved in constructing (and retaining) two parses as opposed to one. However, results from previous studies (Holmes, 1987; Ferreira and Henderson, 1990) suggest that the direct-object (MA) parse is initially constructed regardless of whether the verb is lexically marked as strictly intransitive. Therefore, it could be assumed that for both the ambiguous and unambiguous complement cases (16b and c) both the direct-object and complement parses are constructed and this might be the reason that these two conditions pattern together.

The Delay Parsing Strategy

A third type of parsing strategy for which there is evidence is the Delay model. Here, the parser attempts to defer a syntactic decision until disambiguating information becomes available or until the intervening material accumulates to the point that it can no longer be held unstructured in memory. Frazier and Rayner (1987) reasoned that a suitable ambiguity for this type of strategy would be categorial ambiguity, e.g., the categorially ambiguous word *stop*, which can be used as either a noun or a verb. Whereas other types of ambiguous words tend to be generally disambiguated, a categorial ambiguity (hereafter CA) is often resolved by the category of the word immediately following it. In this case, it would not be especially costly to delay assigning syntactic

structure to a CA until the following word, which is most likely to disambiguate it.

There is, however, a logical problem inherent in the delay theory. That is, how can the parser know when the ambiguity has been resolved if it has stopped (delayed) processing incoming items. Presumably, it doesn't know when it has gotten what it is looking for, so it doesn't know when to stop delaying. In certain cases, this problem can be addressed by incorporating the proposal of Wright and Garrett (1984) that obligatory nodes are predicted. What this means, in effect, is that the parser has already, in the case of an obligatory item (e.g., a main verb), done some advance processing in the form of introducing the obligatory node into the parse tree. In addition, if the syntactic processor includes an automatic function that minimally attempts to determine major syntactic category[3], then the parser will know if the current item matches the obligatory, predicted node. This could allow the parser to make processing decisions based on the present state of the parse tree and the major category of the current word.

One other feature can be incorporated into this characterization of the delay strategy. It is possible that the parser employs a fixed lookahead type of delay, such that it is allowed to delay while examining a limited number of successive items. This is, again, a reasonable strategy in the case of CA's because they are resolved locally, within one or two words.

A further consideration that might cause the parser to adopt a delay strategy for

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[3]Frazier's (1990) principle *Primacy of Syntactic Category Resolution*, that the parser can only act on items for which the major syntactic category has been determined, and experimental evidence (Mitchell, 1987; Ferreira and Henderson, 1990; Clifton, Speer and Abney, 1991) that only major category information is available to guide very early stages of parsing indirectly support this premise.

noun/verb CA's is if a MA strategy is driving the parser. That is, if neither potential parse construction is more "minimal," then the parser has no basis for selection. In this case, the parser would have to delay until another form of disambiguation (e.g., subsequent syntactic context) could serve to disambiguate the sentence.

In Frazier and Rayner's reading experiment, eye movements were monitored to test whether CA's were analyzed by means of a Delay strategy. A sample stimulus set is given in (17).

17a. I know that the (this) desert trains young people.

17b. I know that the (these) desert trains are tough.

When the ambiguous determiner *the* was used, the following ambiguous region *desert trains* could either be a Noun-Verb or Noun-Noun construction. However, when *this/these* was inserted, it served to disambiguate the CA (*trains*) as verb and noun, respectively. The POD for both sentence types is at the word following the CA (*young* or *are*).

The prediction was that reading times for the disambiguated versions (this/these) would be high relative to the ambiguous versions across the ambiguous region. This is because syntactic processing would be on-going in the disambiguated sentences, whereas in the ambiguous sentences, the parser would be delaying processing. Conversely, reading times would be elevated at the POD for the ambiguous (*the*) condition relative to the disambiguated (*this/these*) forms because processing for the ambiguous case is predicted to be delayed until then.

Their results support a delay strategy under conditions of ambiguity. For syntactically

ambiguous sentences, shorter reading times obtained for the ambiguous region, and longer times for the disambiguating region, suggesting that, once the parser encountered an ambiguity, it delayed syntactic processing until the POD.

In contrast, for the previously disambiguated sentences, the opposite pattern was found. Since the ambiguity was resolved by the prior context, all parsing work could be done on the ambiguous region, with slower reading times there, and shorter reading times over the rest of the sentence.

Experiment 3 tested that this result was not due to semantic preference (Milne, 1982). It was possible that there was some preference for version (a) over version (b) for some items. These biases did not predict the results in experiment 3, and they concluded that the semantic preference theory could not account for their pattern of results.

(We will return again to this experiment as it serves as the basis for the experiments reported here.)

We have, then, presented experimental evidence for each major type of parsing strategy - Serial (LP and MA), Parallel and Delay. It is, at least sometimes, apparent that the type of strategy applied by the parser is dependent on the type of ambiguity and the available contextual information.

The next chapter surveys research on the lexical processor, focusing for the most part on questions regarding the lexical access mechanism and the content of lexical entries for ambiguous words.

CHAPTER THREE: LEXICAL ACCESS

The Modularity Issue

Before turning our attention to the process of lexical access, let us consider the makeup of the Human Sentence Processing Mechanism (HSPM) as a whole. The operation of this system is particularly relevant to much of the lexical access research (and to a lessor degree, to studies of syntactic and semantic processing), specifically with regard to context effects, both semantic and syntactic, which will become evident below.

The HSPM is conceived of as a set of processors, each attending to different aspects of language processing - lexical, syntactic, semantic, and pragmatic. These processors can be envisioned either as autonomous or interactive components.

The Modular HSPM

One specified model of this type is that of Forster's (1979) Autonomous Search Model which states that the HSPM is composed of separate sub-processors, each with a specialized operation. The "front end" module is the lexical processor which accepts as input individual words in a speech signal or in written text. This input is used to identify and access words in the mental lexicon, with candidates being activated in a serial fashion in order of frequency.

The results of the lexical search are passed from the lexical processor to a syntactic processor which attempts to incorporate the new item into the current parse structure. The syntactic processor makes use of lexical information as well as internal phrase

structure rules and parsing strategies to construct a syntactically well-formed parse. (We have already seen how this information can interact in the previous section on syntactic processing.)

The message processor receives the output of the syntactic processor and imposes general pragmatic and discourse information in order to complete the analysis. In addition to the subprocessors, there is a separate, decision-making General Problem Solver. Cairns, Cowart and Jablon (1981) adopt a similar model, but without the General Problem Solver. Frazier and Fodor (1978) propose another autonomous system. Because the topic of semantic integration is not a central one here, the different models will not be elaborated.

The main restriction of these, and all autonomous models, is that the separate processors, or modules, must function blindly without having access to information in subsequent modules. That is, there is no feedback from higher-level modules. Effects can occur intramodularly (e.g., some types of semantic priming effects can occur within the lexicon) but not extramodularly (e.g., syntactic context cannot prime lexical access). Therefore, for example, the syntactic processor cannot consult semantic or pragmatic information in order to construct the most plausible parse. In addition, some researchers (Mitchell, 1987; Ferreira and Henderson, 1990) have presented evidence that there is restricted bottom-up information available for initial processing. In these studies, strictly intransitive verbs appeared to be initially parsed incorrectly as direct-object constructions and had to be reanalyzed at a later POD (but see Pritchett, 1991, footnote 9, for a discussion that these verbs were not truly intransitive). This initial lack of use of verb

subcategorization information (supplied by the lexical processor) is further support for a modular HSPM.

The Interactive HSPM

Modular theories contrast with interactive models in which information flows, unrestricted, in the comprehension system. The principle examples of this type of model come from Marslen-Wilson and Tyler (1980) and McClelland and Rumelhart (1981). Interactive models allow for feedback onto lower-level processors from higher-level ones. It is this type of mechanism which predicts that, for instance, the syntactic processor can restrict the lexical processor to accessing a particular part of speech appropriate to the current context.

Which is it?

In order to be able to handle ambiguity, there must be some eventual interaction of information. At some point, higher-level information must be taken into account. Consider, for example, the following sentences (18):

18a. The man saw the boy with the telescope.

18b. The man saw the boy with the kite.

There are two possible readings of (18a) (the man used the telescope to see the boy; the man saw a boy who had a telescope), the first more plausible than the other. Although (18b) has the same sequence of syntactic categories, the preference for the two analyses is reversed. Clearly, extrasentential sources of information are needed to resolve this

ambiguity, i.e., that a telescope, but not a kite, is a likely instrument of seeing.

In our discussion of syntactic processing above, we have seen evidence for the use of different sources of information in disambiguating certain syntactic ambiguities. The pattern that emerged was one in which attributes of both the autonomous and interactive model were observed. Initially, processing is autonomous and proceeds with the benefit of only minimal (category) information as input from the lexical to the syntactic processor. However, at a later stage of processing other information (lexical, pragmatic, semantic) can be applied to fully resolve any remaining ambiguity.

The next section examines more closely the mechanism of lexical access. What the Modularity issue raises here is whether the process of lexical access can be affected by output from the syntactic or message processors, or sentential context. Subsequently, we will survey the experimental evidence for and against semantic and syntactic context effects on lexical access.

The structure of the mental lexicon has implications for how the lexical processor might actually effect activation of specific lexical entries. Because the actual make-up of the lexicon is not a direct concern of the current body of work, it must suffice to say that there are generally two classes of models advocated. These are the threshold models (Morton, 1969; Schuberth and Eimas, 1977), in which the lexicon is viewed as a network of detection units termed logogens by Morton, and the search models, in which the lexical entries are organized into "bins" (possibly by orthographic factors) within which they are ordered by frequency (Forster, 1976).

The threshold models are usually associated with the interactive model of the HSPM

and the context-dependent model of lexical access. The search model is an example of a modular type HSPM and usually incorporates the ordered search or exhaustive access model of lexical access.

The exact details of the operation of these models is beyond the scope of this discussion. Here, we are concerned not with the process by which lexical entries are activated, but with what factors affect which lexical entries are activated. The following discussion considers different models of lexical access.

The Process of Lexical Access

The lexical processor has been modelled in at least three distinct ways, specifically regarding its response to lexical ambiguities. These are the ordered-access model (Forster, 1976; Forster and Bednall, 1976; Hogaboam and Perfetti, 1975), the exhaustive access model (Swinney, 1979; Onifer and Swinney, 1981; Tanenhaus, Leiman and Seidenberg, 1979; Seidenberg, Tanenhaus, Leiman and Bienkowski, 1982), and the context-dependent model (Schvaneveldt, Meyer and Becker, 1976; Simpson 1981). We will first define these models and then review the experimental evidence for how each undertakes the resolution of lexical ambiguity.

The ordered access model states that the lexical processor does not have access to external information with which to resolve lexical ambiguities and, in this sense, is compatible with the modular view of the HSPM. This system, therefore, resorts to serially accessing the alternate entries of the ambiguous word in order of frequency listed in the lexicon.

In addition to the serial nature of this model, the search is terminated when the appropriate word sense is successfully integrated into the sentence. That is, the most frequent meaning is accessed first and shunted to higher-level processors which try to integrate it in the current structure. If this fails, the next most frequent usage is retrieved and passed along. The process iterates until an effective integration occurs, at which time no further alternatives are accessed. Therefore, this is considered a self-terminating search mechanism.

Since the most frequent usage is, by definition, the one most often used, it is usually the case that the entry initially accessed is the one that is appropriate for the context. This often results in an ambiguous word being functionally indistinguishable from an unambiguous one since the processor only accesses the one meaning.

The exhaustive access model describes a mechanism in which all lexical entries (meanings, usages) of a word are activated, without regard for any contextually available or top-down information. It, too, is consistent with a modular HSPM. In fact, the lexical processor must be able to effect multiple access because no outside information is available to it for use in selecting the appropriate usage. The selection process is given over to post-access processes that can avail themselves of these other sources of information. For example, if the syntax can disambiguate the lexical ambiguity, then the syntactic processor will be able to use this information to choose the appropriate meaning from those offered by the lexical access process. Another feature of this model is that inappropriate entries that have been activated either quickly decay or are actively suppressed immediately following successful integration of the appropriate lexical

alternative.

The main theoretical difference between this and the ordered access model is that the ordered access model is self-terminating, that is, it is not necessarily the case that all meanings of an ambiguous word will eventually be activated. One variant of exhaustive access might be that all meanings are accessed, but they become available and are conveyed in order of frequency, with higher frequency alternatives being activated more robustly and more rapidly.

The context-dependent model (also referred to as the selective access model) is distinct in that it does provide for external sources to guide lexical access. The initial activation of an ambiguous word can be affected by such information as syntactic, semantic, and discourse contexts, and pragmatics. In this way, the separate subprocessors can each exert influences on the lexical processor based on their individual knowledge of the current state of comprehension.

The more extreme variant of this model predicts that only the contextually and pragmatically appropriate meaning will be accessed and that other meanings will not be activated at all. This mechanism would then be functionally identical to that of ordered access in cases where the most frequent usage was the contextually appropriate one, that is, only one alternative would be accessed and the system would be oblivious to the ambiguity. Because of the overlapping predictions made by these three models, some researchers have been vigilant to include tests of both dominant and subordinate meanings of ambiguous words.

The other major theoretical concern, as in studies of most cognitive processes, is to

insure that the process which is being examined is actually the one that is being measured. In other words, the temporal aspect of the process necessitates the use of methodologies that can truly examine the locus of the effect. Special on-line measures have been developed in order to observe (albeit indirectly) which lexical entries have been initially activated (e.g., cross-modal priming and naming tasks). This is especially important in testing theories such as the exhaustive access model which predicts that the inappropriate meanings are quickly deactivated. It is entirely conceivable that an initial, transient, multiple access state could be missed unless a suitable methodology is employed.

Although the lexical decision task has been used extensively to study lexical access, this method has come under increasing scrutiny. Many researchers have replaced lexical decision with the naming task, or have contrasted both methods using one set of stimuli. Naming and lexical decision tasks have been found to be differentially sensitive to pre-lexical (access) and post-lexical (selection and integration) processing (West and Stanovich, 1982). The lexical decision task is purported to include a post-access decision stage, called "meaning integration" or "post-lexical coherence checking" (Cairns, Cowart and Jablon, 1981; De Groot, 1985). Because this secondary stage takes time, higher level syntactic processes might begin to affect performance on the lexical decision task. Therefore, it is likely that lexical decision times would include subjects' reactions to context with regard to the target word as well as the initial word-nonword decision time. In contrast, the act of naming is assumed to occur more quickly, before the effect of context has been realized.

The next section indirectly touches on these methodological concerns in reviewing the experimental evidence for each of these lexical access models. As mentioned previously, because the current work pertains to effects of syntactic context, most of the literature reviewed here will specifically concern itself with this problem, although some important work on semantic context effects will also be described.

Evidence for The Ordered Access Model

To test for ordered access, it is necessary to vary stimulus frequency. Hogaboam and Perfetti (1975) noted that previous studies had intentionally chosen their ambiguous stimuli to be equiprobable, that is, the alternate meanings had equal frequencies. They employed an ambiguity detection task in which subjects were asked to listen to sentences and decide whether the final word had more than one meaning. This task necessitates access of at least two meanings of the ambiguous word. Some sentences had biasing contexts toward the dominant (more frequent) meaning and some toward the subordinate meaning. Responses were slower for the former.

Hogaboam and Perfetti reasoned that since subjects were faster when they had to access the dominant meaning in the subordinate biased stimuli, the dominant meaning must have been already accessed. In contrast, in the dominant bias condition, since the subordinate meaning had not initially been activated (because the successful integration of the dominant meaning had terminated the search without activating the less frequent one), subjects had to now access the subordinate meaning in order to answer "Yes" for the ambiguity task.

Therefore, they concluded that the dominant meaning is accessed first, with subordinate meanings being activated in order of frequency only when the dominant meaning fails to be integrated into the context. These results were replicated by Holmes (1979).

Forster and Bednall (1976) came to the same conclusion using a syntactic function task. In this task, subjects are asked whether a second word is a syntactically correct continuation of the first. They used stimuli such as *the box* vs. *to box* (which are noun/verb ambiguities) and controls such as *to door*. Subjects were faster when the word was placed in the syntactic context that conformed with its dominant usage (determined by subject ratings), suggesting that access is ordered by frequency.

Forster and Bednall also carried out an ambiguity detection experiment. Their results showed subjects responded "Yes" to ambiguous words faster than "No" to unambiguous controls. They inferred that when subjects encountered the second meaning for the ambiguous words they were able to answer "Yes" and terminate the search. However, in accessing the single meaning of the unambiguous word, an exhaustive search had to continue in order to be able to answer "No." This, again, was evidence for a terminating search mechanism.

Rayner and Frazier (1989) have recently presented evidence for an immediate selection model. They used stimuli as in (19).

19a. George said that the wire informed John that his aunt...

19b. George said that the wire surrounded the entire...

In addition to the different resolutions of the ambiguous word *wire*, they varied whether

the ambiguous word was equibiased or had a strong dominant meaning (norms obtained from two independent groups of subjects).

They found that equibiased homographs were fixated longer than biased homographs in a neutral context. In the equibiased case they reasoned that both meanings were accessed and successfully integrated into the current syntactic structure (ambiguous with respect to either meaning). However, the reason that the biased forms were fixated less was that the alternate meanings were accessed serially, by frequency. As soon as the dominant form was accessed, it was successfully integrated with the context, thus terminating the access of any other meanings.

The conclusions were supported by their data for sentences with prior disambiguating context. When the syntactic context demanded the subordinate meaning, reading times were longer on the biased ambiguous word, reflecting the required access of the subordinate meaning after the attempt to integrate the dominant meaning failed because of ungrammaticality.

Evidence for The Exhaustive Access Model

Evidence for exhaustive lexical access has generally come from two types of studies, phoneme-monitoring and priming. In phoneme-monitoring, the subject is instructed to listen to a sentence while simultaneously monitoring for a particular phoneme. Increased sentence complexity results in greater processing demands and more attention to sentence comprehension. Consequently, less attention is available for the secondary task, phoneme-monitoring, resulting in longer monitoring times.

Priming studies (often, cross-modal) require the subject to listen to or reading a stimulus sentence. At some point after the ambiguous word is presented, the subject is probed with a target for lexical decision (deciding whether or not the string of letters represents a legal word). This word is either semantically related or unrelated to one of the two meanings of the ambiguous word. Faster lexical decision times for the target word are considered to be evidence that there has been some activation of the semantically related meaning of the ambiguous word (see discussion of Meyer and Schvaneveldt, 1971 below).

Test sentences usually include some biasing context for either the dominant or subordinate meaning, although frequency is not always systematically varied. Varying the context enables a test of the hypothesis that context will effect selective access of the appropriate meaning of the ambiguous word.

Initially, phoneme-monitoring was the most popular method. However, in 1978 Mehler, Segui and Carey criticized this paradigm pointing out that the ambiguity variable was confounded with word length which they subsequently showed to be a factor in this task. In addition, Newman and Dell (1978) also found that word length, frequency and the initial phoneme of the target affected the phoneme-monitoring task. Nevertheless, the data from phoneme-monitoring will be presented.

Using a phoneme-monitoring task, Foss (1970) presented evidence that sentences which contained ambiguous words resulted in slower phoneme detection times after the ambiguity than did unambiguous sentences. Foss and Jenkins (1973), again using a phoneme-monitoring task, included contexts that biased toward one of the meanings of

the ambiguous word. They obtained the same results as Foss (1970) and concluded that context was not used to reduce the processing load imposed by the ambiguity.

Cairns and Kamerman (1975) found that if they postponed the target phoneme a few syllables beyond the ambiguous word, then monitoring latency returned to the control level. They determined that all meanings were initially activated, with context selecting the appropriate meaning soon after.

Using a cross-modal priming task, Swinney (1979) was able to show multiple access for ambiguities that had equiprobable meanings. Sentences such as (20) were used with targets presented for lexical decision at either position 1 or 2 (approximately 1.5 seconds later).

> 20. Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several (spiders, roaches, and other) bugs $_1$ in the $_2$ corner of his room.

The material in parentheses provided the optional semantic context. The lexical decision targets were either semantically related to the contextually appropriate meaning of the ambiguity (*ant*), semantically related to the inappropriate meaning of the ambiguity (*spy*), or unrelated (*sew*).

Swinney reported that, for targets presented at position 1, lexical decisions to both types of related lexical targets were faster than to the unrelated control. This was taken as evidence that both meanings had been accessed in the lexicon. The strong biasing context was not sufficient to suppress the access of the unrelated meaning. However, data collected at position 2 showed faster lexical decision times only for the contextually

appropriate meaning. Swinney interpreted these results as meaning that initial lexical access is unaffected by biasing context, with all meanings accessed. Context is then applied in order to select the appropriate meaning from among these candidates. In addition, the fact that only the appropriate meaning was still facilitated three syllables later was support for the rapid decay of the activation level of the other unrelated meaning.

A further experiment in which highly lexically biased words were used (one meaning is substantially more frequent than the other) yielded similar results. The final conclusion was that strong frequency and semantic context constraints were inadequate to prevent the access of the less frequent meaning.

Speculating that access might be constrained by information other than semantic, Prather and Swinney (1977) devised stimulus sentences that incorporated CA's (e.g., *cross*). The correct reading of these words was signalled by the syntactic context in which they occurred. A cross-modal priming task produced results consistent with the exhaustive access model. Both grammatical and ungrammatical meanings of the ambiguous word were facilitated, implying that syntactic context could not constrain lexical access to the grammatically correct choice.

Some researchers have developed a chronometric method which allows them to incorporate a stimulus onset asynchrony (SOA) condition in which the target word can be presented milliseconds after the ambiguous word is encountered. This allows inspection at very short (e.g., 0 and 200msec) delays which makes it possible to more directly and accurately measure the time at which the selection of the appropriate meaning

is executed.

Tanenhaus, Leiman and Seidenberg (1979) made use of this manipulation in a cross-modal priming task with noun/verb ambiguities in syntactically biasing contexts (e.g., *I bought the watch.* vs *I will watch.*). A target word related to the noun or verb meaning was presented for naming at different times following the sentence. At 0msec SOA, naming was facilitated for words related to either meaning, i.e., there was no effect of biasing context. However, naming at 200msec SOA was facilitated only for the biased reading.

Tanenhaus, et al. were in agreement with a model in which all alternatives of an ambiguous word are initially accessed with the appropriate meaning being selected within 200msec. They actually found a slight advantage for contextually appropriate meanings at 0msec SOA, but this difference did not reach significance.

In a response to methodological criticisms, Tanenhaus and Donnenwerth-Nolan (1984) attempted to replicated the data of Tanenhaus et al. (1979) and Seidenberg et al. (1982). The previous research had included sentences such as *They began to train.* Since these were auditory stimuli, the *to* was ambiguous (*to* vs. *two*), therefore, the syntactic context did not constrain the reading of *train* to either a noun or verb form. In order to rectify this, they replaced the *to* with a *tuh* sound, thus constraining the next word to the verb form. The results showed that listeners access multiple readings of an ambiguous word even when one of the readings is syntactically inappropriate and concluded, as did Tanenhaus et al. and Seidenberg et al., that syntactic context does not influence the initial lexical access.

Evidence for the Context Dependent or Selective Access Model

A study that is often cited as providing the initial evidence for a robust associative priming effect in lexical access is that of Meyer and Schvaneveldt (1971). They used a lexical priming paradigm in which a single priming word influences the lexical decision of a subsequently presented related target word. In their experiment subjects showed faster lexical decision times to targets that were associatively related to previously presented primes (e.g., the pair *doctor-nurse*) than to unrelated controls.

At first, these results were interpreted as troublesome for the modularity theory because it appeared that lexical access for the related target had been affected by a previously presented word, which, in effect, was a semantic context. This put into question the autonomous principle of the modularity theory, that lexical access is unaffected by context (or by the state of other, higher-level processors).

However, the application of the spreading activation theory of the mental lexicon (Collin and Loftus, 1975) can resolve this discrepancy. In this theory, each entry in the lexicon is represented by a node. The nodes of associated words are connected. These nodes are activated upon recognition, thereby spreading activation to connected (associated) nodes. The higher the activation of a node, the faster it is recognized. The targets were recognized faster than controls because their activation levels were elevated due to priming by the previously presented associated word. Forster (1979) has reasoned that this type of contextual effect does not violate the principle of autonomy because it is due to intralexical conditions and not induced by external knowledge.

Swinney and Hakes (1976) attempted to correct what they thought to be a potential weakness in previous studies. Their concern was that contexts had not been sufficiently constrained. Consequently, they constructed stimulus sentences with strong semantic biases toward one reading of the ambiguous word. In a phoneme-monitoring task, they found that neutral contexts resulted in an increased processing load, whereas prior disambiguating contexts showed no such effect. This was taken to indicate that strong disambiguating context can result in restricted lexical access.

These results were replicated by Cairns and Hsu (1980) although, subsequent to other results they had obtained, they chose to interpret the results to mean that the context affected a decision stage after multiple lexical access had occurred.

In 1981, Goodman, McClelland and Gibbs used a lexical decision task in single word contexts: a target word preceded by a syntactically appropriate word (*he-sent*), a semantically related word (*doctor-nurse*) or an unrelated word. They found that syntactically and semantically appropriate (one word) contexts significantly reduced lexical decision times when presented in blocks. However, this effect disappeared when the conditions were mixed, which implied a subject-imposed strategy for handling these types of stimuli. They concluded that appropriate syntactic context can facilitate word recognition in a lexical decision task. The obtained effect might reflect the facilitation of the selection of the appropriate reading at the post-access stage.

A further demonstration of syntactic context effects on lexical decision was reported by Lukatela, Kostic, Feldman and Turvey (1983). They presented some data from Serbo-Croatian which contains inflected nouns that normally follow prepositions that determine

the form of the noun inflection. This is a circumstance which affords a special advantage because, unlike in English, word class does not have to be violated in order to create ungrammatical stimuli - the syntactic environment can be manipulated without any confounding semantic alteration.

Their stimuli consisted of prepositions followed by nouns that were either syntactically appropriate or not (e.g., masculine preposition-masculine noun vs. feminine preposition-masculine noun). As mentioned, the differences in the stimuli constitute a purely syntactic distinction.

Lexical decisions were made to the noun forms. Lukatela et al. found that appropriate syntactic pairings produced faster lexical decisions and concluded that this was evidence for what they termed grammatical priming. However, their use of the lexical decision task calls into question the locus of their effect, because lexical decision is purported to include both the time to access a word from the lexicon and a post-access decision stage.

Perhaps one of the strongest cases presented in favor of syntactic context effects was put forth by Wright and Garrett (1984). Being critical of the confounding of semantics and syntax in stimuli of previous studies, they attempted to separate out semantic and syntactic context effects by using semantically anomalous, but syntactically correct (or incorrect), sentences, such as in (21) below:

21a. If your bicycle is stolen you must formulate.

21b. *If your bicycle is stolen you must batteries.

The lexical content was exactly the same for the two versions of the stimulus

sentence. Only the syntactic category of the target word (underlined) varied (verb or noun). Although target words varied across conditions, this information was thought to be superfluous as semantics was not a useful dimension in these stimuli (but see Experiment II, below).

The result of the first experiment was that the syntactically legal continuations produced shorter lexical decision times to targets. This demonstrated a strong effect of syntactic environment on a lexical decision target.

In Experiment II, syntactic variants of the same word were used as targets (e.g., *translates* and *translation* for the verb and noun, respectively) in order to determine that previous data resulted from syntactic and not interpretive differences. In addition, they added adverb and adjective targets to the same context strings to test if the effect could be generalized to other syntactic categories.

Although shorter reaction times were observed for syntactically preferred forms for the noun/verb continuations, no differences were found for the adjective/adverb targets. Wright and Garrett hypothesized that this result was due to the fact that the parsing system predicts heads of phrases, which the verbs and nouns (but not the adjectives and adverbs) functioned as in these stimuli. A subsequent experiment was designed to test whether these effects were due to some general salience of nouns and verbs or whether, in fact, some factor involving phrasal heads could account for the differences.

Stimuli in which adjectives did (22a) or did not (22b) serve as heads of phrases were constructed for another experiment:

22a. The interesting clock seems very <u>tolerable</u>

22b. Your visiting friend should enjoy tolerable.

The results for the condition in which the adjective served as the head of a predicted phrase (22a) showed faster lexical decision times which, taken together with the results of Experiment II, provided further evidence that phrasal role is the significant factor.

Wright and Garrett postulated a predictive mechanism (locate phrasal heads) or a top-down process that builds in advance a structure in which the target word can act as head. They were not able to conclude that their effect was a result of syntactic category guiding lexical access.

It is important to reiterate that this was a lexical decision task and, as such, could have reflected post-access processes. Concerned with this possibility, West and Stanovich (1986) replicated Wright and Garrett's findings with both the lexical decision and naming tasks. This replication was contrary to the negative results that Seidenberg et al. (1984) obtained when they tried to replicate the single word syntactic priming effect found in the Goodman et al. (1981) study.

It must be noted that, in their last experiment in which they incorporated a neutral condition (*the next word will be...*), the data clearly showed that the context effects were primarily inhibitory. They advised that the choice of neutral condition is a difficult one and that these results must be viewed with caution. With regard to inhibitory effects, other research (Motley, Baars and Camden, 1981) has demonstrated inhibition in the pronunciation of syntactically ill-formed phrases which has been ascribed to output editing effects and this might be the source of what West and Stanovich were measuring in their naming data.

Although West and Stanovich conclude that their results did not provide conclusive evidence that the locus of the syntactic context effect is lexical, the finding that naming and lexical decision yielded equally large differences is an important indication.

What the experiments in this section all share in common, besides their conclusions, is a problematic methodology. Lexical decision is not the task of choice for probing prelexical processes and the phoneme-monitoring task has been called into question. Even though West and Stanovich (1986) contrasted lexical decision with naming, it appears that their naming results could be attributed to an inhibitory process (usually a slow mechanism) which suggests that the locus of their effect is post-lexical.

Experiments showing evidence both for and against context effects

In several experiments, Seidenberg, Tanenhaus, Leiman, and Bienkowski (1982) used the same experimental paradigm as Tanenhaus et al. (1979) but also included noun/noun homographs in their stimuli (see review of Tanenhaus et al. listed above). Some of these results supported the exhaustive access model and some the context dependent model.

The first experiment used a neutral sentential context with noun/noun ambiguous words (e.g., *If Joe buys the straw* with the naming targets being *hay* or *sip*). The results indicated that multiple access occurred, with targets related to either meaning of the ambiguous word facilitated at 0msec. (Experiment 2 and 4 showed a semantic context effect and are reported together below.)

Whereas in the first experiment, the sentential contexts were both syntactically and semantically neutral, in experiment 3 both noun/noun and noun/verb ambiguities were

presented in appropriate contexts. In (23a and b), the syntactic bias is towards the noun or verb form of the ambiguous word *rose*, and in (23c and d), the semantic bias is toward one or the other noun reading of *spade*. However, no words semantically or associatively related to these ambiguous words are present. (Naming targets are in capitals.)

23a. They bought a rose. FLOWER

23b. They all rose. FLOWER

23c. You should have played the spade. CARD

23d. Go to the store and buy a spade. CARD

The same pattern of results was seen for these stimuli as for those in experiment 1, at 0msec either reading of the ambiguity showed facilitation in the naming task, but only one persisted after 200msec. This replicated the noun/verb ambiguity findings of Tanenhaus et al. (1979). In addition, the data suggested that biasing syntactic context cannot effect selective access of the syntactically correct meaning, rather it serves to facilitate the selection process.

A sample stimulus set from their second experiment follows in (24):

24a. Although the farmer bought the straw

24b. Although the farmer bought the wheat

24c. Although the farmer bought the soda

The target after each one was either *hay* or *sip*. A word (*farmer*) that was semantically related to only one of the meanings of the ambiguous word provided the context. The first example (24a) ends in an ambiguous word, each of its meanings are related to one of the two targets. The phrase in (24b) concludes with an unambiguous word that is

related to the context, and (24c) ends in an unrelated control.

SOA was used in conjunction with a cross-modal priming paradigm. At 0msec, targets related to the contextually appropriate reading, but not the inappropriate reading, of the ambiguous word were facilitated. This suggests that the biasing context resulted in selective lexical access of the contextually appropriate meaning. This conclusion was contrasted with the results of the first experiment in which a neutral semantic context was used and multiple access prevailed.

The basis for this selective access is the same as for that attributed to the Meyer and Schvaneveldt (1971) data and is specified in the spreading activation model of the lexicon by Collins and Loftus (1975). In this view, selective access is a consequence of processing within the lexicon itself. Appropriate meanings of the ambiguous words were activated by virtue of their being connected in the lexicon to words used in the semantic context (e.g., *farmer* is connected to, and therefore activated only the *hay* meaning of *straw*, and not the *sip* meaning). At 0msec only the primed reading showed evidence of being activated, implying that alternate meanings are accessed according to level of activation (here the activation level of the lexically primed *hay* meaning of *straw* has been elevated by the previous presentation of the word *farmer* and so it is first to be accessed).

Their fourth experiment applied both semantic and syntactic contexts and included noun/verb ambiguities as well (e.g., The gardener cut the *rose*). Again, the noun/noun ambiguities showed selective access at 0msec, with only the targets that were related to the primed meaning showing facilitation. However, no significant effect of priming was revealed for the noun/verb ambiguities, both related and unrelated targets were facilitated.

This caused Seidenberg et al. to conclude that there are two types of context - lexical priming (semantic) and nonpriming (syntactic). The former produces selective access by intralexical activation of semantically related words. The latter can only facilitate the post-access selection process. In addition, it was inferred that categorial (noun/verb) ambiguities are not able to be primed in the way that noun/noun ambiguities are.

One criticism of this work, that they themselves point out, is that the frequency of the different meanings was not controlled. This is essential as their model includes the assumption that meanings of an ambiguous word are accessed in order of their activation level which is largely determined by frequency.

Noting the significance of timing in the process of lexical access and context effects, Seidenberg, Waters, Sanders and Langer (1984) carried out a series of experiments using both naming and lexical decision to identify the loci of contextual effects on lexical processing.

Seidenberg, et.al. first replicated Goodman, et al. (1981) and found that there was indeed a small facilitative effect due to syntactic relatedness when the task was lexical decision. However, these results did not obtain in the naming task. They did obtain facilitation effects for both tasks with their semantic context stimuli. In discussing the two tasks, they point out that, in naming, subjects do not have to discriminate between words and nonwords, therefore, there is no decision stage involved. Their results suggest that there are two possible loci for contextual effects on word recognition; prelexical effects due to spreading activation in the lexicon of semantically related items, and postlexical (post-access) effects due to subject judgments of the relatedness of word and

context.

West and Stanovich (1986) felt that one weakness in the method of some experiments that prevented them from showing a syntactic context effect was the use of one-word syntactic contexts. However, Lukatela et al. (1982) did obtain large facilitation effects in a lexical decision task with one-word contexts. Carello, Lukatela and Turvey (1988) believed that the important difference between studies that demonstrated a syntactic context effect and those that did not could be that semantic plausibility interacted with syntax in the stimuli of studies in which no context effects were found. In fact, they state that the stimulus confounding must be interpreted as meaning that no purely syntactic effects had been demonstrated. They argued that putative syntactic effects actually might have been due, in part, to a semantic confounding, citing specifically the stimuli of Wright and Garrett (1984), West and Stanovich (1986), and Seidenberg et al. (1984, e.g., stimulus pairs such as *men/planet* and *whose/swear* were both semantically implausible and syntactically incongruous).

In an attempt to replicate Seidenberg, et al. (1984), Carello, et al. employed both a lexical decision and naming task and contrasted syntactic priming with associative priming in one-word contexts with Serbo-Croatian preposition/noun pairs (e.g., MOJ DOKTOR vs. MOJA DOKTOR*). These types of stimuli had previously displayed a robust syntactic context effect in both the naming and lexical decision tasks (see Lukatela, et al., 1982).

Facilitation was reported in both the naming and lexical decision tasks for associatively primed targets, but facilitation only in the lexical decision task for

syntactically congruent targets, replicating Seidenberg, et al. (1984).

They concluded that when plausibility does not co-occur with grammatical violations, syntactic context does not affect lexical access in naming, which appears to be immune to the kinds of automatic, postlexical coherence checks that influence lexical decision. Lexical decision, on the other hand, was susceptible to postlexical influences like syntactic congruity checks. Their associative priming effects were attributed to intralexical spreading activation.

Mixed Model - differential effects of frequency or context

Some studies show that reaction times to the contextually appropriate or the more frequent meaning (whichever variable is being investigated) are facilitated. However, although the inappropriate or less frequent meaning is slower than the preferred meaning, it is still faster than the reaction times for unrelated material. These results are not always significant in all experiments, but are reported hear to illustrate the pattern. Some examples follow.

Holmes (1979) found, in a meaningfulness judgment task, that subjects responded more slowly when the less frequent meaning was appropriate, suggesting that the dominant meaning could be accessed more quickly. Carpenter and Daneman (1981) had their subjects perform a reading task on sentences containing homographs that were ambiguous with respect to their pronunciation. Subjects more often pronounced the ambiguous word in the more frequent form when it occurred in a strongly semantically biased discourse context. They concluded that frequency and context exerted influences

on the retrieval stage of lexical access.

Swinney (1979), in his cross-modal priming task with noun/noun homographs in semantic contexts, reported both meanings of the ambiguous word were facilitated, but there was a slight advantage for the biased meaning.

Onifer and Swinney (1981) conducted a similar experiment to Swinney (1979) but manipulated differential frequency of the meanings of the ambiguous words. Their results supported the multiple access theory, but, there was a small advantage for the dominant meaning in the dominant biasing contexts and the subordinate meaning in the subordinate biasing contexts.

Oden and Spira (1983) used a Stroop color naming task to investigate whether both meanings of an ambiguous word are activated regardless of any biasing context. Their biasing contexts consisted of sentence context (Running over that glass could burst your tire.), semantic context (*axle, wheel, tire*), syntactic context (*the tire*), and no context (*tire*).

After the context, a target was presented (in the previous example, *rubber*). Oden and Spira reported that both meanings of ambiguous words appear to be activated, even in the presence of biasing context. However, the degree of activation of each meaning depended on its agreement with the syntactic and semantic constraints of the context.

This group of experiments illustrates the importance of controlling frequency of ambiguous stimuli and of using balanced biasing contexts which allow closer inspection of which entries of an ambiguous word are activated and to what extent.

In the previous discussion on lexical access, we have seen that the naming task is an

essential diagnostic in examining the process of lexical access, and much research using this methodology has found evidence for syntactic context effects on lexical processing. However, proper stimuli are generally lacking in most of these experiments (e.g., Wright and Garrett, 1984; Goodman et al. 1981; Forster and Bednall, 1976).

In the next chapter, other methodological problems of past work are discussed and the motivation for the current research is outlined in detail, with results and discussion of the experiments following.

CHAPTER FOUR: THE EXPERIMENTS

Motivation for these Experiments

One thing that becomes clear from the previous literature review is that no one theory of lexical or syntactic processing accounts for all the experimental data. Some proponents of serial parsing report that lexical bias (e.g., lexical preference for subcategories) affects syntactic processing strategy, others that parsing is initially determined by internal strategies of the parser (MA), and still others conclude that the parser uses a parallel or a delay procedure. Some studies find discourse context and/or lexical bias can lead to selective lexical access and some find that exhaustive access prevails in any manipulation. Of course, it is often the case that the studies that agree with each other have used similar types of experimental stimuli and paradigms. One is tempted to conclude that the lexical and syntactic processors are most likely somewhat adaptable, changing strategies based on available information and task demands. However, before doing so, it might be advisable to rethink some of the problems inherent in these experiments, at least in the case of systematic ambiguity.

Except in rare instances (possibly the work in Serbo-Croatian[4] and Frazier and Rayner, 1987), the literature, as Carello et al. (1988) point out, is sorely lacking in well-

[4]Although syntactic context effects have been shown in Serbo-Croatian, more work needs to be done in English, which has a deeper orthography. The shallow orthography of Serbo-Croatian allows for the naming task to be performed using only grapheme-to-phoneme correspondence rules, potentially bypassing the lexicon. This makes it potentially a different task than in English, where the lexicon must be consulted for a correct pronunciation.

controlled stimuli, that is, materials that are not confounded with semantic or pragmatic variations. In order to properly study lexical and syntactic context effects on lexical and syntactic processing, at least three variables must be controlled. First, the semantics of the ambiguous word itself must be controlled while allowing its syntactic properties to vary. In other words, this word must be systematic, with meanings for the different parts of speech being semantically related.

The second variable is the syntactic environment. Sentences which are identical up until the ambiguous word are preferred, with difference only introduced at the POD. Also, if the experimental objective is to examine the effect of previous syntactic context on the processing of the ambiguity, then disambiguating context must vary minimally from the ambiguous control version of the sentence. One way to achieve this is by substituting a disambiguating determiner for an ambiguous one, such as *these* for *the* (see below for example).

The last variable that must be experimentally manipulated is the relative frequency (lexical bias) of the different senses of the ambiguous word. In addition to the above, a full sentential context for the ambiguous word is preferable to a one-word syntactic context.

Added to these factors regarding the materials, two task requirements must also be met if the time course of any effects is to be adequately observed: 1) the comparison of on-line tasks that employ the same materials is necessary, both one that taps earlier processing (e.g., naming) and one that reflects later processing (e.g., lexical or syntactic decision), and 2) it is essential to use a task that yields measures for each word in the

sentence in order to obtain a "play-by-play" account of the different processes involved in sentence comprehension.

One researcher who maintained a consistent syntactic context in his materials was Milne (1982). He used categorially ambiguous stimuli in a controlled sentential environment in order to explore effects on sentence processing (e.g., The sentry stands on guard. vs The sentry stands are green.). The underlined phrase includes a CA which can be parsed as a noun-verb phrase or a noun-noun. In a task in which subjects were asked to report whether they thought the presented material represented a complete sentence, subjects were slower to respond for sentences in which the resolution of the CA in the phrase went against its (independently rated) bias.

Milne concluded from these results that the syntactic parser seems to defer to the semantic parser when faced with ambiguous sentences such as above. In effect, when a potential ambiguity is encountered which the syntactic processor cannot immediately disambiguate, the semantic processor is consulted to choose the more frequent meaning of the ambiguous item in the context. This is the essence of Milne's Semantic Checking Hypothesis. Unfortunately, there are some methodological problems with this experiment. For example, some of Milne's stimuli were unsystematic (e.g., *rocks*), and, although the semantic preference for the ambiguous phrase was manipulated, the relative frequencies of the different parts of speech of the ambiguous word itself were not controlled for frequency. The disambiguated control sentences differed from the ambiguous condition in a relatively major way in that the word preceding the CA was often changed to a different part of speech (this manipulation was actually necessary to test the theory). For

example, *the toy rocks* was compared with *the little rocks*. Also, as is typical of many of the early studies, his measure was post-sentential. This incurs two problems for interpretation. One is that this type of task only measures whole sentence comprehension time so that local effects can not be observed word-by-word, and the other is that measurements for late tasks are most likely to reflect several levels of processing, so it is difficult to attribute results to any one process in sentence comprehension.

Frazier and Rayner's (1987) eye-movement study of categorial ambiguity answered many of the methodological concerns above. They effectively reduced the semantic confounding of their syntactic stimuli. The purpose of the research was to investigate the strategy of the parser (serial, parallel, delay) upon encountering local ambiguities, i.e., the type that are usually resolved within one word.

Specifically, in their second experiment, they used systematic categorial ambiguities like those shown in (25). Four versions of each sentence frame were generated (categorially ambiguous region in italics):

25a. Some of us weren't aware that the *church pardons* very few people.

25b. Some of us weren't aware that the *church pardons* were rare.

25c. Some of us weren't aware that these *church pardons* were rare.

25d. Some of us weren't aware that this *church pardons* very few people.

Upon examining these stimuli, the first thing that might become obvious is that the four versions are identical through the ambiguous region, except for the use of different determiners. Also, the POD (word following the ambiguous region) can be compared for the versions with the same part of speech resolution (e.g., 25b and c) because the word

at the POD is identical. This satisfies both the requirement to present the ambiguous word in identical environments for the different conditions and to minimally vary the preceding context when previously disambiguating the CA. In addition, note that the two parts of speech of the CA differ minimally in semantic content. (Results from this experiment are summarized in the Literature Review section above.) However, Frazier and Rayner's failure to apply the other necessary constraints on task and materials motivated the current experiments which attempt to address the following shortcomings.

First, in order to ascertain whether lexically stored information can affect lexical access and/or alter the strategy of the parser, it is necessary to manipulate single word frequencies (lexical biases). Frazier and Rayner's categorially ambiguous items (e.g., *pardon*) did not vary systematically with respect to their noun/verb usage frequencies as recorded in Francis and Kucera, 1982 (hereafter FK), an objective measure of lexical preference. Indeed, they state unequivocally that an attempt was made to exclude ambiguous words for which one variant was clearly subordinate to the other.

Since experimentally varying the lexical bias of ambiguous items could help to distinguish both between the LP vs. the MA parsing strategy and exhaustive vs. selective lexical access of the alternate meanings of the ambiguous word, this variable was manipulated in the current experiments so that some materials had a dominant noun usage, some a dominant verb usage and some were equiprobable.

Second, the eye-movement task of Frazier and Rayner presents two problems. Both Carpenter and Daneman (1981) and Tabossi (1988) have contended that eye fixation times cannot discriminate different levels of processing in reading (perceptual, retrieval and

integration) and, therefore, cannot be used to infer lexical access processes. Ford (1983) has stated, likewise, that simple eye fixation measures do not appear to reflect subtle underlying processes.

In addition, inherent in the task is an inability to obtain precise measurements for each word separately. Often the measure is given as mean time per character or total reading time over a region, which is how Frazier and Rayner report their data. In fact, in a more recent paper, Rayner and Frazier (1989) admit that this is a flaw and have since measured processing at the POD rather than the entire disambiguating region (as they had done in previous studies) in order to obtain a more precise measure there.

There is also a problem with Frazier and Rayner's statistics in that they only report a subjects analysis. Clark (1973) describes the necessity for both a materials and a subjects analysis in order to draw correct conclusions from the data.

One of the eye-movement task's more attractive assets, its similarity to natural reading, also causes a dilemma which is that subjects' reading is uncontrolled. This results in subjects regressing back to previous material and a failure to fixate some words altogether which makes it difficult to determine what is the appropriate measure of reading time for a particular word. A related problem stems from the fact that the span of perception is asymmetric to the right of fixation (Rayner, 1978) which results in some items being skipped over and not fixated. This necessitates averaging the time spent fixating the previous word over both itself and the word that is skipped. In addition, because an item to the right can be "seen" before it is actually fixated, this item could influence the processing of the previous item. Therefore, it is difficult to know where a

word is having its effect. In fact, sometimes an effect can be seen at a point in the data before any manipulation has occurred in the stimuli.

These difficulties are in contrast to certain of the subject-paced or experimenter-paced methods in which the subject sees only one word at a time and must make a decision on that word. This yields word-by-word decision times and does not permit regressions to earlier material since previous words are deleted as they are read. The single word precision of these tasks may even be preferable to that of eye-movement studies, considering that the latter's data represent fixation times over multi-word regions.

A presentation paradigm such as one of the above, combined with a response task such as naming, allows for inferences about what is happening where and when. The present experiments employ controlled stimulus presentation in conjunction with either a late or early decision. These include subject-paced visual presentation with continuous syntactic decision (SPVP with CSD), rapid serial visual presentation (RSVP) with post-sentential recall, and naming. It is believed that this is a reasonable combination of methods to permit deductions about the whats, whens and wheres of lexical and syntactic processing.

Another consideration in doing the present experiments is that it is always important to replicate results using different tasks and materials. Mitchell and Holmes (1985) point out that subject-paced reading tasks and eye-movement tasks have yielded similar effects with major variables like word frequency, and the direct comparisons between these two procedures have not uncovered any important qualitative differences. Ford (1983) observes that the expense of collecting and analyzing eye-movement data serves as a

deterrent to its use. In fact, Ferreira and Henderson (1990) found similar results using both eye-movement and non-cumulative SPVP reading paradigms, although their results from a subsequent cumulative SPVP task did not agree. It seems, therefore, justifiable to attempt to use subject-paced methods as a less expensive and more convenient substitute for eye-movement data in reading.

Looking again at the stimuli in (25), one of Frazier and Rayner's interests was with the first word of the ambiguous region, here, *church*. They contended that, although this word occurs most often as a noun, it has a derivative usage as an adjective. However, the word *pardons* is certainly categorially ambiguous in these two versions, acting as a verb in (25a and d) and as a noun in (25b and c). The word *church* can be said, arguably, to be used as a noun in both cases.[5] Therefore, it appears that the more well-defined, explicit CA is in the second position of the ambiguous region, and the present experiments address themselves to this noun/verb CA.

Although the need for Experiments I and II was motivated by the above, the incentive for Experiment III arose from the results of the first two. It was thought that these data could be interpreted in more than one way and Experiment III was run to attempt to rule

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[5]Frazier and Rayner say in a footnote that they will ignore the possible analysis of the ambiguous string as a series of conjoined nouns because various factors including the principle of MA suggest that this analysis is not considered. Therefore, they consider noun phrases such as "the church pardons" to be analyzed as Determiner-Adjective-Noun based on stress pattern, i.e. compound stress is not obligatory. But, they also admit that the correct analysis for these phrases is not clear. If one were to follow their account, however, virtually every uninflected noun would be temporarily ambiguous with respect to category, as it might also be an adjective if succeeded by a noun. Here, we consider the first noun to be categorially unambiguous and focus exclusively on the SCA of the second word following the determiner (e.g. "pardons").

out one of the possible theories. In addition, an attempt was made to address whether CA's other than the noun/verb type entail implementation of a delay strategy by the syntactic processor.

Experiment 1

Looking at Systematic Categorial Ambiguities Using Subject- and Experimenter-Paced Visual Presentations

This experiment was proposed to investigate the role of syntactic context and lexical bias on the lexical and syntactic processing of CA's (e.g., *stop*) in sentences using both subject-paced and rapid-serial visual presentation methods. The reason for choosing these paradigms can be illustrated by comparison with other popular methods for studying lexical and syntactic ambiguities. For example, post-sentential tasks provide only a global measure of the difficulty of sentence processing and do not show the locus of this difficulty. Paradigms such as cross-modal priming and phoneme-monitoring measure the processing only at one predetermined position. And, eye-movement data are very expensive and time consuming to collect and analyze to the point where deductions about parsing processes can be made.

Aaronson and Scarborough (1976) developed the original technique of subject-paced visual presentation (SPVP) in which the subject controls the presentation of the materials and reads for comprehension. Ford (1983) adapted the SPVP paradigm in order to render it sensitive to on-line syntactic processing. She noted a tendency for subjects to rhythmically press the response key while reading for comprehension and, therefore,

implemented a secondary task to break subjects' rhythm. The secondary task was a lexical decision on each word. This was effective in preventing rhythmic reading and, using this paradigm, she obtained evidence for on-line syntactic processing differences.

The adaptation of the SPVP method employed here in Experiment Ia is the continuous syntactic decision (CSD) task, also developed by Ford, which allows word-by-word monitoring during sentence processing. Subjects make a syntactic decision on each word of the sentence (can the sentence still be completed grammatically after this word?), and this decision time has also been found to reflect the parsing complexity of the sentence (Slutsky, 1989; Loring, 1990; Holmes et al, 1989).

Experiment I was designed to investigate how CA's are parsed and whether lexically stored information can affect their parsing. It is an attempt to replicate the findings of Frazier and Rayner (1987) with similar materials but different methods. The stimulus sentences contained categorial (noun/verb) ambiguities, the type which were found by Frazier and Rayner to be parsed using a delay strategy. The ambiguous sentences were resolved in both the noun and verb directions by a subsequently presented word. Each ambiguous sentence form had an unambiguous control that was matched with it at all positions except for the determiner, thus allowing clear comparisons by word position. As mentioned above, these materials had minimal semantic variation, both the noun and verb forms being derived from the same meaning.

In addition, to examine whether the LP strategy is used to select one of the readings of the CA, the lexical biases of the ambiguous words as recorded in FK were directly manipulated. If the higher frequency form is selected as the default in a syntactically

ambiguous environment, this would lead to faster syntactic decision times at the POD when the sentence is resolved in the direction of the higher frequency form. The current experimental design allowed this to be tested.

Experiment Ia

Looking at Categorial Ambiguities using Subject-Paced Visual Presentation with Continuous Syntactic Decision

Method

Subjects

Twenty Hunter College undergraduates who were native speakers of English served as subjects in this experiment. Participation in the experiment was offered as one means to obtain extra credit points in an undergraduate statistics course.

Materials

A sample stimulus set is given below.

26a. After midnight the bus *stops* at every corner.

(AV - ambiguous syntactic context, verb resolution)

26b. After midnight this bus *stops* at every corner.

(DV - disambiguated syntactic context, verb resolution)

26c. After midnight the bus *stops* are less crowded.

(AN - ambiguous syntactic context, noun resolution)

26d. After midnight these bus *stops* are less crowded.

(DN - disambiguated syntactic context, noun resolution)

There are three experimental parameters manipulated in these materials. The first variable is the part of speech resolution (i.e., noun or verb) of the systematic CA in the sentence. In examples (26a) and (26b) above, the ambiguous word *stops* is used as a verb, and in (26c) and (26d) it is used as a noun.

The second variable is syntactic context ambiguity. In (26a and c) the context is syntactically ambiguous due to the determiner (*the*). However, in (26b and d) the CA has been previously disambiguated by the determiner *(this* or *these).*

The third parameter is the lexical bias of the CA (*stops*). In these materials, the noun and verb usages have different relative frequencies (frequency counts were determined for each part of speech for each ambiguous word from FK). Some categorially ambiguous stimuli had a noun bias, some a verb bias and some were equibiased with respect to noun and verb usage.

The materials consisted of 21 sentence frames. In seven of these, the ambiguous word had a noun lexical bias (N/V ratio averaged 82:18, with a minimum of 71:29), seven had an ambiguous word with a verb lexical bias (N/V ratio averaged 22:78, with a maximum of 37:63), and seven had no lexical bias (average bias 50:50, with a maximum ratio of 62:38).

In summary, the materials consisted of 21 sentence sets, each of which had four versions. Two of the four (DN and DV) were previously disambiguated by a preceding unambiguous determiner (e.g., *these*). The other two sentences (AN and AV) contained an ambiguous determiner (*the*) and were not disambiguated until the word immediately following the ambiguous word (one as a noun and one as a verb). These materials, then,

are analogous to the 16 sentence frames used by Frazier and Rayner (1987), with the exception that Frazier and Rayner did not include lexical bias as an experimental variable.

All versions of each sentence were identical up until the POD (the word after the CA) except for the type of determiner. This resulted in a design with the variable subjects crossed with lexical bias, syntactic context ambiguity, part of speech resolution, and word position. When sentences was the repeated measures variable, they were nested in lexical bias and crossed with syntactic context ambiguity, part of speech resolution, and word position.

Subjects saw examples of each sentence type, but never more than one version from a particular sentence set. Periods were omitted in order to avoid cuing subjects that the end of the sentence had been reached. The experimental stimuli were intermixed with 16 stimuli from another experiment and 60 filler items with a variety of lengths and structures, most of which were ungrammatical at some position in the fragment. This resulted in approximately half of all stimuli being ungrammatical at some point in the sentence and half being grammatical. All experimental and filler items are presented in the Appendix.

Procedure

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

> This is called a syntactic decision task. You will be showing sentences to yourself one word at a time. Before you can see the next word, you judge whether the

sentence is grammatical up to that point. If the sentence is still grammatically acceptable you will press the "+" key on the keypad on the right side of the keyboard. If the sentence is no longer grammatically acceptable you will press the "0" key on the keypad. Pressing the "+" will allow you to see the next word in the sentence. Pressing "0" terminates the sentence. The sentence may become unacceptable at any time.

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

The first 10 sentences or parts of sentences will be practice items. The experimenter will stay with you during these items to answer any procedural questions, and then the regular items will begin. You will receive about a hundred sentences, with a short break in the middle. Make your choices as quickly as possible while trying not to make errors.

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

When ready to continue, the subject pressed the enter key and practice trials immediately followed. A single word at a time was visible in the middle of the screen, centered in a rectangular box to facilitate fixation. The word remained on the screen until the subject pressed either the "+" key (indicating that a grammatically acceptable sentence could continue) or the "0" key (indicating that the sentence could not be grammatically continued with that word). When the subject pressed the "+" key, the word was erased and overwritten by the following word in the sentence which was also centrally displayed both in the box and on the screen. Thus, the technique used a noncumulative and centrally displayed presentation of single words, none of which was followed by a period.

When the last word of the sequence had been shown, the box disappeared briefly and was replace with another one containing the "ready" signal for the next trial. If, during a trial, a subject pressed the "0" key to indicate that a sequence was no longer grammatical, the screen was cleared and the "ready" signal appeared for a new trial.

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

Predictions

Considering first the effect of syntactic context, if the parser adopts a serial syntactic preference strategy such as MA, it is not clear that the AN and AV materials will differ from each other at the POD. MA does not prefer one parse over the other. This is because neither of the alternate parses (D-N-N vs. D-N-V) requires more nodes to be postulated, assuming that obligatory nodes are predicted by the parser (see discussion of Frazier, 1990, below in General Discussion).

However, Wright and Garrett (1984) and Bever (1970) have suggested that the parser acts on a syntactic preference of Determiner-Noun-Verb, assigning the first possible word to be the noun and the next to be the verb. This syntactic preference would predict that the AV condition would yield faster CSD times at the POD than the AN stimuli which would show a gardenpath effect at this position. This is because the parser would default to the preferred Det-N-V construction in both ambiguous cases but would only be wrong in the AN case and, thus, would have to reanalyze the phrase as Det-N-N at the POD.

A parallel parsing strategy with cost would predict that the AN and AV conditions will show longer times in the ambiguous region than the DN and DV stimuli because of the need to construct and hold both of the possible parses for the ambiguous case. If the parallel parses are ranked, and there is, in fact, a syntactically preferred verb parse, there might be an increase in CSD times at the POD for the AN stimuli reflecting the cost of having to accept the unpreferred alternate parse (D-N-N). If, as Gorrell's evidence suggests, there is no cost associated with parallel parsing, then the ambiguous stimuli should pattern with the disambiguated versions, or at least with the one that requires the greater amount of processing (i.e., takes more time) because the parser will have to construct both the easier and more difficult parse for the ambiguous stimuli.

The delay strategy predicts that processing in the ambiguous region for the AN and AV materials should be less than that for the DN and DV stimuli reflecting on-line parsing of the latter, but delay of processing for the former over this region. In addition, CSD times should increase at the POD for both ambiguous conditions relative to the disambiguated ones indicating the delayed parsing being done at this point for both the

AN and AV stimuli.

Turning now to predictions concerning the lexical bias factor, if a serial LP strategy is operating then the preferred parse should be for the dominant form of the CA. That is, sentence resolutions that go counter to the bias (DV and AV noun bias and DN and AN verb bias sentences) should show a garden path effect at the POD, whereas those that agree with the resolution (DN and AN noun bias and DV and AV verb bias sentences) should be easier to process there.

If there is both an effect of syntactic context and lexical bias, then perhaps the easiest parses for the syntactic processor will be the syntactically disambiguated conditions that agree with the bias (DN noun bias and DV verb bias); the slowest would be the ambiguous conditions that go against the bias (AN verb bias and AV noun bias).

The locus of the effect of lexical bias, if any, is also informative. An early effect of lexical bias in the ambiguous region would imply that the syntactic processor makes initial use of lexical information whereas a late effect, at or after the POD, would suggest that bias is used only in a post-integration checking procedure.

Results

Two analyses of variance were used to analyze the data. In one, subjects, treated as a random effect, were crossed with the fixed variables part of speech resolution (noun or verb usage of the systematic CA), syntactic context ambiguity (ambiguous or disambiguating determiner), lexical bias (noun, verb or even), and word position (five locations in the sentence). Position 1 was the word before the determiner, position 2 was

the determiner, position 3 was the first noun, position 4 was the categorially ambiguous word, and position 5 was the disambiguating word (POD). In the other analysis, materials (the random effect) were nested in bias but crossed with all other fixed variables.

The grand mean syntactic decision time was 789 ms. Word position was highly significant in both the subjects and materials analyses: $F_1(4,76) = 13.00$, $p<.0001$ and $F_2(4,72) = 40.2$, $p<.0001$, with the determiner position having the shortest time. This main effect for word position suggests that subjects were reading for comprehension and not merely pressing keys.

The other significant main effect was for part of speech resolution with the noun resolution condition being slower overall than the verb resolution condition (820 vs. 759 msec, respectively): $F_1 (1,19) = 12.48$, $p < .002$ and, marginally, $F_2 (1,18) = 3.81$, $p < .06$. This main effect was due to the much longer CSD times at position 3 for the DN condition and at position 5 for the AN condition (seen below in Figure 2).

Two interactions were found to be significant. Syntactic context ambiguity by word position : $F_1 (4,76) = 10.12$, $p < .0001$ and $F_2 (4,72) = 12.22$, $p < .0001$, indicated that sentences with the unambiguous determiner were parsed differently from their ambiguous controls, with the disambiguated versions yielding significantly lower CSD times than the ambiguous ones at the POD (758 vs. 962 msec, respectively). This is shown in Figure 1.

The other significant interaction was the 3-way interaction of syntactic context ambiguity by part of speech resolution by word position, though only marginally so in the subjects analysis: $F1(4,72) = 2.71$, $p<.05$, and $F2(4,76) = 2.27$, $p<.07$ in Figure 2. This

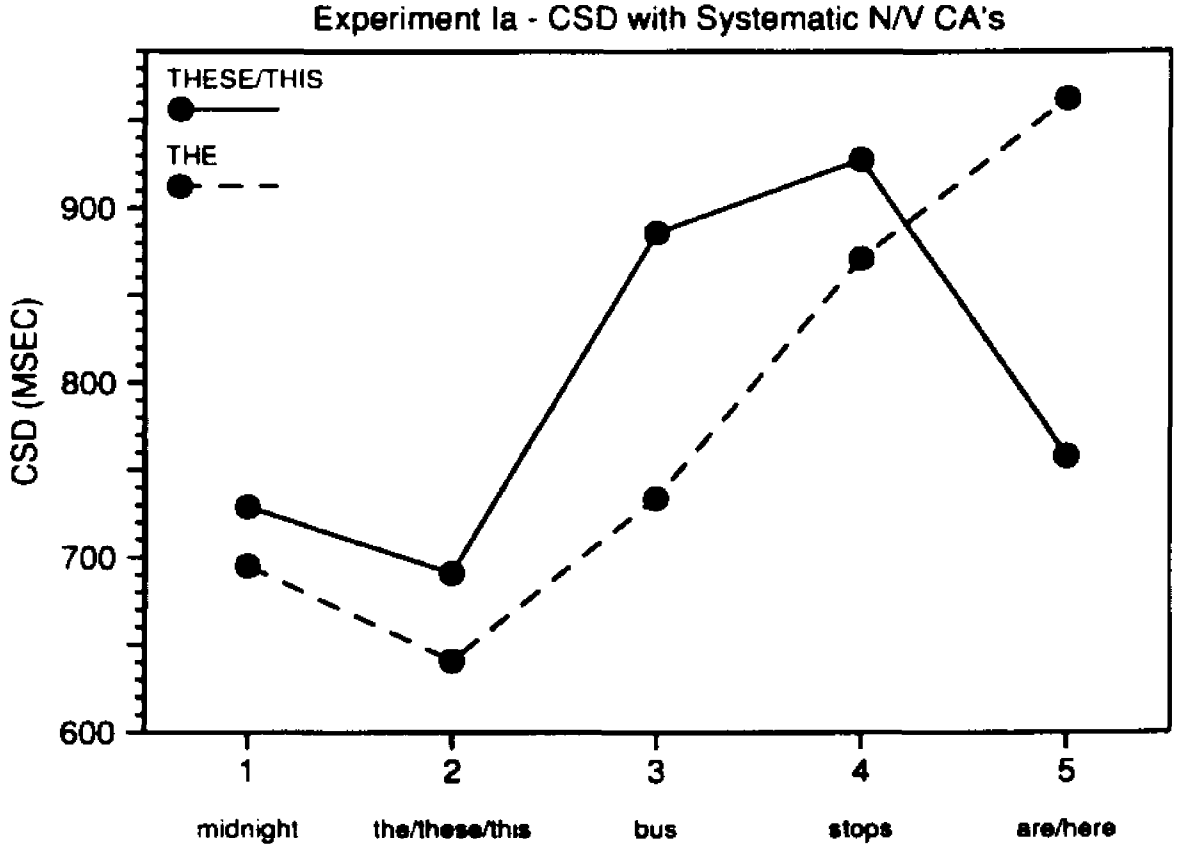

Figure 1. Experiment Ia - Mean CSD (msec) as a function of Syntactic Context Ambiguity (ambiguous or unambiguous determiner) and position in sentence

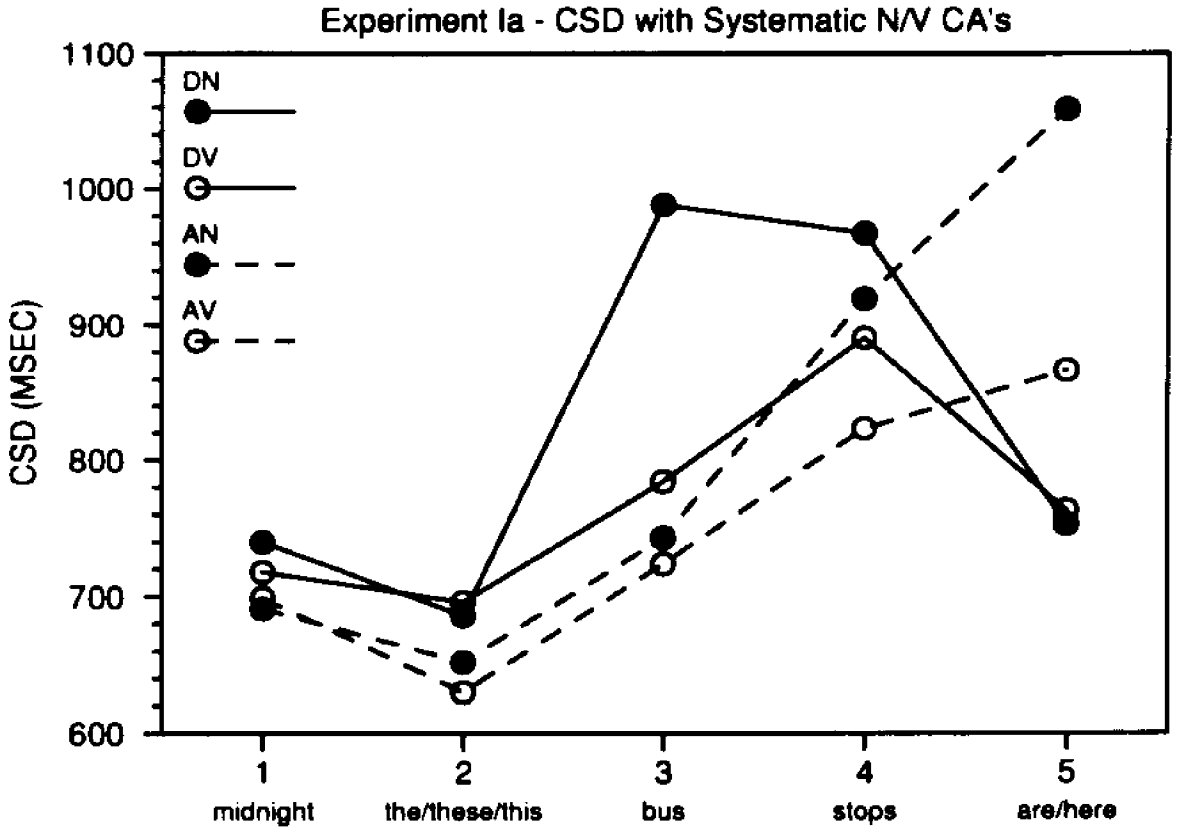

Figure 2. Experiment Ia - CSD (msec) as a function of syntactic context ambiguity (ambiguous or unambiguous determiner), part of speech resolution (noun or verb) and sentence position.

suggests that the ambiguity of the determiner affects the parsing of the verb and noun constructions somewhat differently. To determine the specific location of the significant differences, the verb and noun resolutions were analyzed separately. This 3-way interaction of syntactic context ambiguity by part of speech resolution by word position can be seen in the two separate Figures 3 and 4, one for verb and one for noun resolution, respectively.

For the verb resolution stimuli (Figure 3), where the CA acted as a verb (... *this bus stops at* ...), significant differences were found between ambiguous (AV) and disambiguated versions (DV) at the POD (position 5)$F_1(1,76) = 4.07$, $p<.001$, and $F_2(1,72) = 5.64$, $p<.001$. The processing load is higher at the POD for the AV condition.

In Figure 4, when the CA functioned as a noun (... *these bus stops are* ...), as in the verb analysis described above, significant differences were found at the first noun and at the POD, with the AN condition requiring more processing time than the DN condition: $F_1(1,76) = 20.95$, $p<.0001$ and $F_2(1,72) = 13.11$, $p<.0001$.

In addition, error rates were calculated for these materials. Table 1 shows the frequency of "ungrammatical" judgments classified by sentence type and word position. The errors are not distributed evenly for each sentence type across the positions: $X^2(9) = 20.2$, $p<.025$, with more errors at position 3 for the DN sentences and more errors for the ambiguous versions at the POD. Lexical bias was not found to be a significant factor at any position tested.

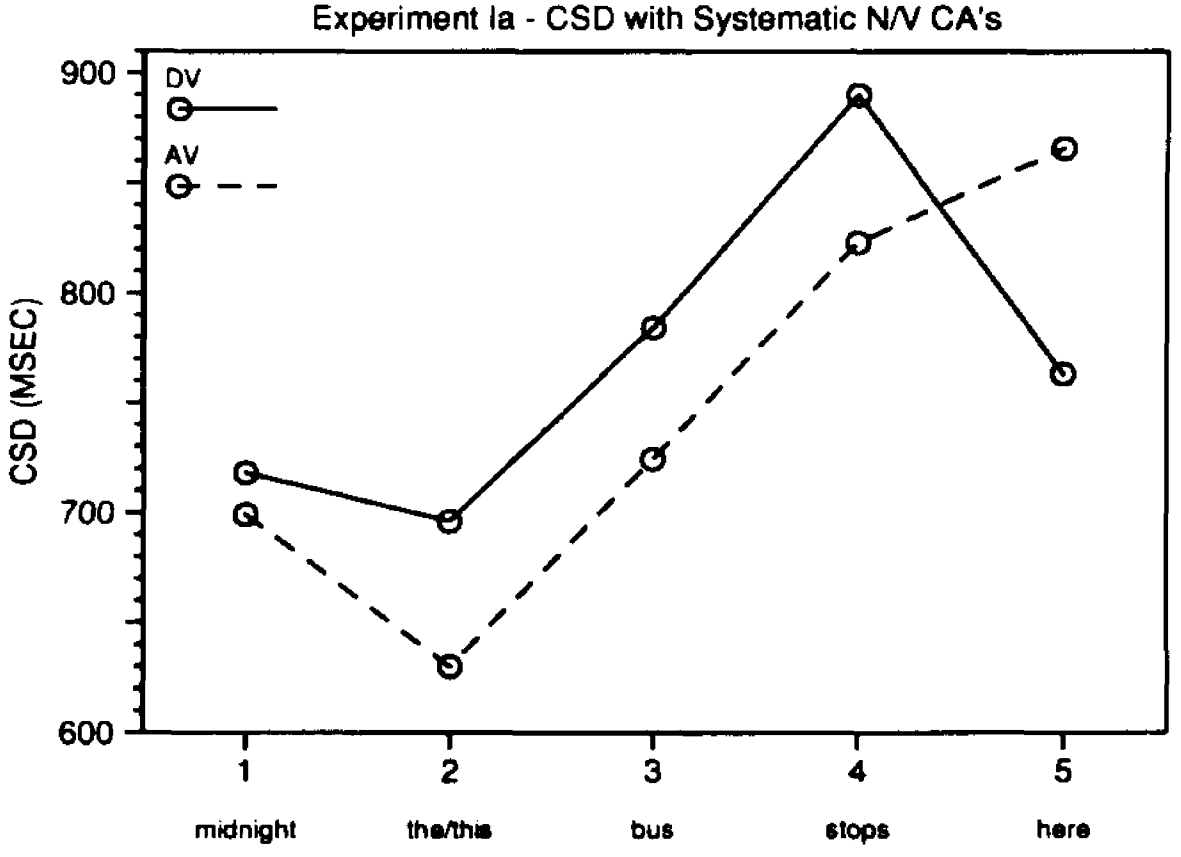

Figure 3. Experiment Ia - CSD (msec) as a function of syntactic context ambiguity and position in sentence, verb resolution stimuli.

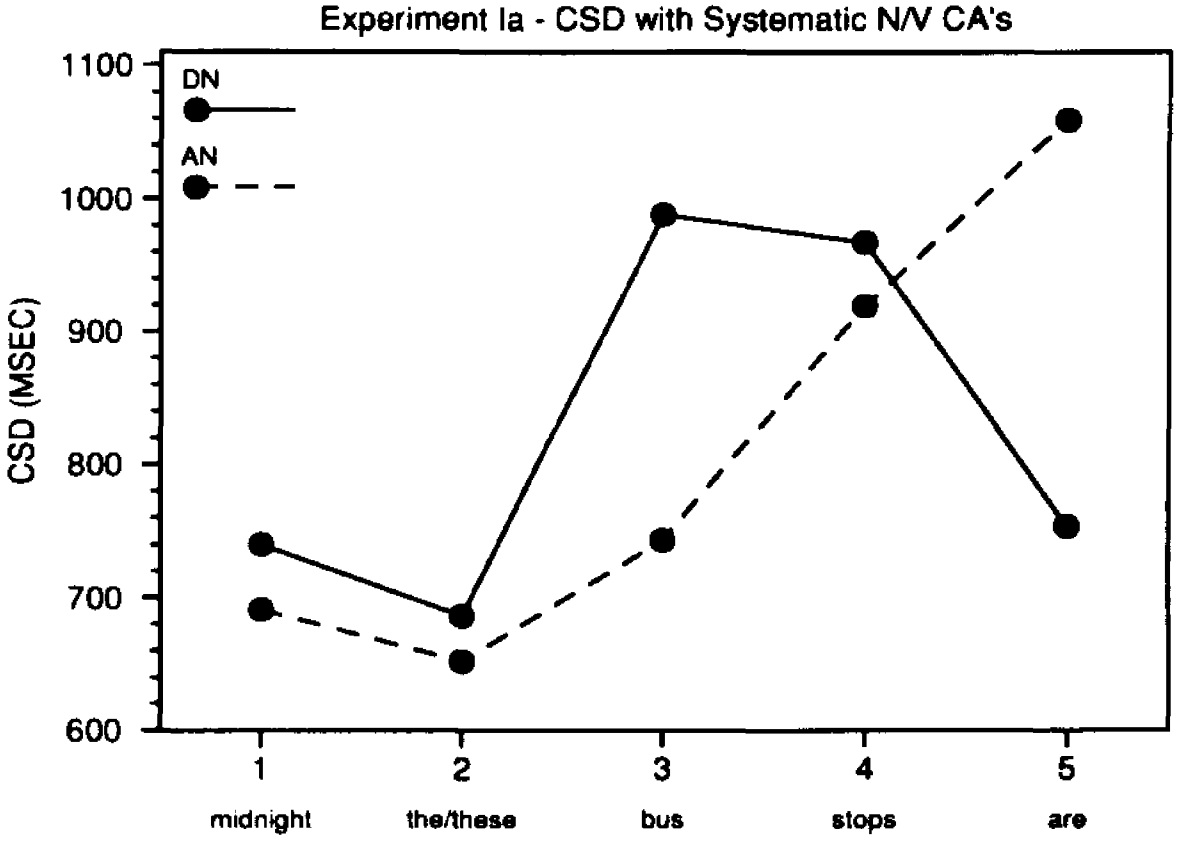

Figure 4. *Experiment Ia - CSD (msec) as a function of syntactic context ambiguity and position in sentence, noun resolution stimuli.*

Table 1. Number of "ungrammatical" judgments in Experiment Ia by syntactic context ambiguity, part of speech resolution and position in sentence.

	Position in Sentence			
	Determiner	N1	N/V	POD
DN	0	6	4	2
DV	0	0	0	0
Total	0	6	4	2
AN	0	0	2	6
AV	1	0	0	4
Total	1	0	2	10

Discussion

In general, these results can be interpreted as supporting a delay strategy for CA's, although they do not replicate all of the findings of Frazier and Rayner. Decision times for ambiguous sentence versions are significantly longer than their matched disambiguated controls at the POD. However, no significant differences were found between the ambiguous and disambiguated conditions in the ambiguous region (which consisted only of the CA).

The 3-way interaction conveys the most information in the separate Figures 3 and 4. In Figure 3, which shows the verb resolution condition, there is a drop at the POD for the DV relative to the AV case, which is characteristic of the delay strategy. A similar picture is depicted in Figure 4 for DN and AN sentences.

However, these data do not support Frazier and Rayner's finding that processing load in the ambiguous region was greater for the disambiguated conditions. This is related to the question of what does, in fact, constitute the categorially ambiguous region. Frazier and Rayner argued that the first word after the determiner in the ambiguous region occurred most often as a noun, but had a derivative usage as an adjective as well. They, thus, considered both words after the determiner to be categorially ambiguous. This interpretation is not taken here. The present experiment assumes that there is no categorial ambiguity in the first noun, but only regarding its status as the head of the phrase. Since a delay strategy for the CA would presumably only be implemented in cases where the parser becomes aware of an ambiguity (e.g., when more than one syntactic category is accessed), it would seem clear that the delay is not effected until the

CA. Therefore, at the earliest, the effects of delaying would not be seen until at least the CA. In the present experiment, evidence for delay is observed at the POD, the word immediately after the CA.

There is, however, a significant increase in decision time at position 3 (the first noun), which probably reflects the difficulty of parsing a phrase like "these bus" because of the obvious disagreement in number. The increased decision times at this location for the DN sentences show that the parser is computing the structure. Frazier and Rayner report a similar result for their DN sentences. However, as previously mentioned, they explain the cause of the three-way interaction as a combination of the complexity of the adjectival categorization of the first word of the ambiguous region and the earlier disambiguation point for the DN rather than as an indication that a failed attempt had been made to assign the head noun.

Frazier (1990; note 2) again cites this result as being more probably due to the complexity of arriving at an appropriate meaning for these sentence types. This explication seems to depend on the relation between the two words in the ambiguous region; however, the effect is seen at the first word, presumably before the second word has been read, so an interpretation that depends on a relationship between the two could not account for this effect.

In addition, other studies have presented evidence that Adjective-Noun constructions are easier to process than Noun-Noun constructions (Kroll and Potter, 1984; Dommergues, Frauenfelder, Mehler, and Segui, 1979), suggesting that a noun modifier function is preferred for the first word.

Upon inspection of their reading time/character data in Figure 5, it appears that Frazier and Rayner's results pattern with those reported here, with the DN condition taking longer for the average reading time per character at the position of the first noun. (Frazier and Rayner's first experiment differed from the second in that, although both employed CA's, the second included only systematic categorial ambiguities. The data for Experiments I and II were collapsed for presentation here because the construction of the stimuli was the same at the position of the first noun and because they report similar findings for the two experiments.)

It seems clear from the data presented in Figure 5 that Frazier and Rayner are not really getting the results that they claim, that is, elevated reading times over the ambiguous region for the disambiguated (DN and DV) materials, which they say is evidence for on-line processing. Their results, as mentioned above, appear to be similar to those reported here, with longer processing times in the ambiguous region only for the DN condition, a finding they explain as being caused by the syntactic complexity of taking the first noun as a modifier.

Therefore, the more likely interpretation of both these and Frazier and Rayner's results is that the parser is, indeed, concerned with assigning the head noun and that is why the singular noun after the determiner *these* in the DN sentences disrupts parsing.

In summary, two distinct processing strategies emerge from Experiment Ia. In the disambiguated case (DN and DV), processing is carried out on-line, with times significantly decreasing after the part of speech ambiguity, at the POD. Here, the correct "path" is followed, presumably due to the disambiguating determiner, and the structure

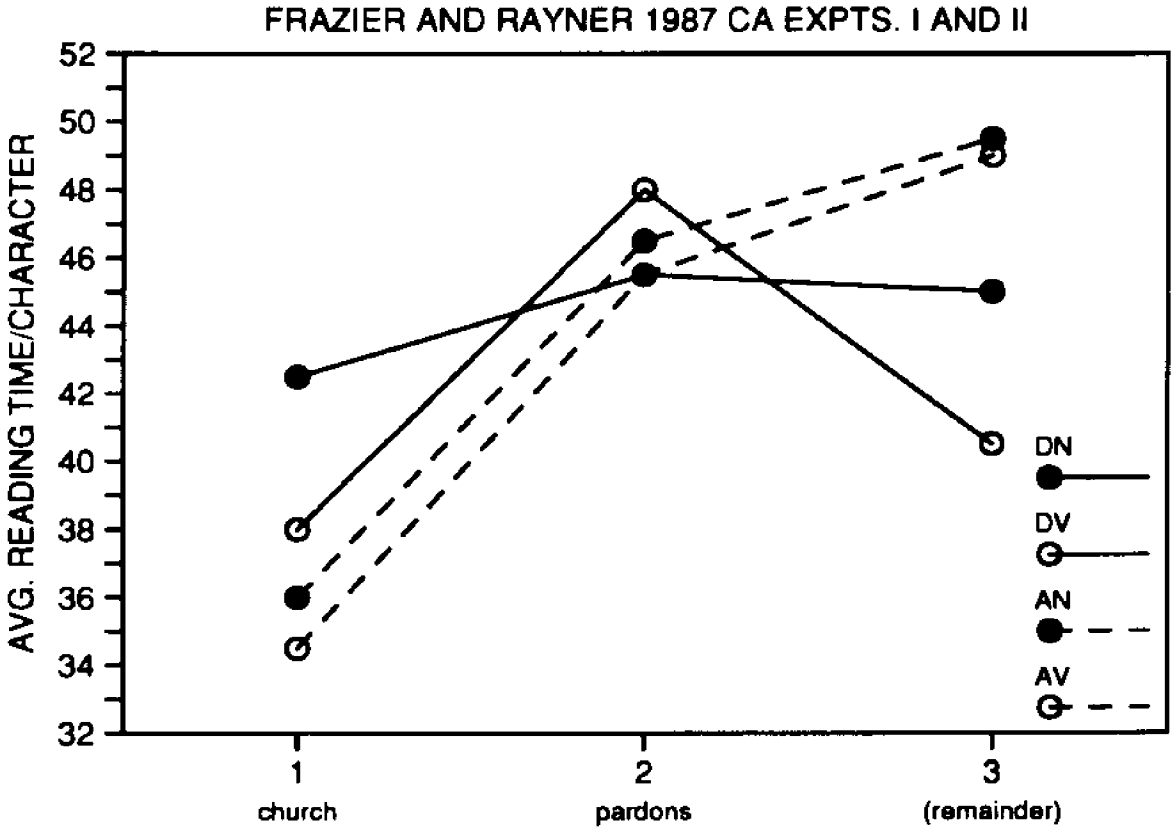

Figure 5. Frazier and Rayner's 1987 Eye-Movement Data for Systematic and Unsystematic Categorial Ambiguity: Average Reading Time/Character in msec.

is resolved correctly. However, in the ambiguous cases (AN and AV), a delay pattern emerges. There is a much greater increase in decision time at the POD for *both* the noun and verb resolution conditions. This is an indication that the delayed parsing is being done here.

Let us lay out the parser's actions in the ambiguous case. When a determiner is encountered the parser predicts a head noun node, initially circumventing any intermediate (modifier nodes) in the parse tree. The next item is a noun, and so the parser assigns that to the head noun node of the noun phrase currently under construction. Once the head noun is assigned, the noun phrase is completed and a verb node can be projected. The next word, however, is a noun/verb CA.

The parser has three options here, serial, parallel or delay. It can apply one of two serial parses, assigning the CA as either a noun or verb. If it chooses the noun interpretation, the noun phrase must be reopened and restructured. The previous noun must be unassigned as the head noun and a new, intermediate modifier node must be added to the noun phrase construction to incorporate it. Then the CA must be assigned as the head noun. This is obviously quite a lot of work for the parser.

What of the serial verb parse? Since the parser has already projected a verb node, the least resistant path would be to assign the CA to this existing node as the main verb. However, if the CA is resolved as a noun, it has even more work to do. Not only must it unassign the head and restructure the noun phrase, but it must also reassign the main verb.

The parallel account would dictate the parser to build parse trees for both the noun

and verb resolutions of the CA. This has its own costs associated with it, both of time and space. However, the data do not reflect the computational predictions of the parallel model, specifically, the parallel model does not account for the increase for both ambiguous versions of the sentence at the POD.

There is a third possibility. The parser can minimize its losses by implementing a delay strategy. Here, the parser can leave the existing parse construction (Det-HeadNoun-Verb) temporarily intact, but delay assigning the categorially ambiguous item until the next word. This is a reasonable strategy since the alternatives are certainly costly and the parser would, presumably, try to avoid this complex reshuffling. In addition, CA's are most often resolved locally. Thus, the parser can expect to receive disambiguating information imminently, here at the very next word. If the CA is resolved as a verb, the correct parse has been predicted and the category assignment of the CA is relatively easy. However, if the CA is resolved as a noun, the predicted parse (Det-HeadNoun) would be incorrect and the syntactic processor would have to rebuild the noun phrase. Therefore, the outcome predicted by the delay strategy is more efficient than that of either serial parse, or the parallel parse. This delay account explains the pattern that was observed in the AV and AN conditions at the POD in Experiment Ia.

Now, looking more closely at the significant difference in the CSD times for the AN vs. AV condition at the POD, it is assumed that the longer times for the AN stimuli are attributed in part to the need for a full reanalysis (from Det-HeadNoun to Det-Noun-Noun) as opposed to only minimal processing for the AV condition. Again, this is because the AV sentences were resolved in agreement with the syntactic preference for

Determiner-HeadNoun-Verb whereas the AN stimuli had to be resolved in the nonpreferred (Determiner-Noun-HeadNoun) direction.

However, because the AN condition resulted in longer CSD times at the POD than the AV condition, the serial strategy is not so easily dismissed. The fact that the CSD times for the AN condition increase significantly more than for the AV condition at the POD might lead one to construe these results as supporting a serial parsing strategy, as opposed to the delay strategy proposed above. But, how might a serial strategy have yielded this pattern of results? Suppose that upon encountering the CA, the majority of subjects select the verb resolution parse and a minority opt for the noun resolution. This would mean that, at the POD, in the AV sentences, most subjects will have made the correct choice while a minority will be graden-pathed. However, at the POD in the AN sentences, the majority will be garden-pathed, while only a few subjects will have made the correct choice. Although this would account for the ordering of the means (AN, AV, DN and DV; Figure 2) at the POD, a closer examination of the data rules out this explanation.

If subjects are sometimes following one serial parse and other times following another in the AN and AV conditions, the variance for these sentences should be higher than for the DN and DV conditions. In the item analysis, the variance for the AN condition is significantly different from the variance for the DN condition: $F(20,20)=2.55$, $p<.05$. However, the variance for the AV condition is not significantly different from either the DV or DN conditions: $F(20,20)=1.23$ and 1.69, respectively. This suggests that something different is occurring in the parsing of the AN stimuli compared to the other

three conditions. And, the relatively low variance of the AN condition implies that there was no bimodal distribution of these data, as was postulated above for the serial account.

However, it is not sufficient simply to examine these variances. It is necessary to go back and inspect different measures of variances for the data in the materials and subjects analyses. In the subjects analysis, only six of the twenty subjects had mean CSD times for the AV condition that were equal to or less than those for the DV condition. This means, at best, only about 25% of the subjects were using a serial strategy with a preference for the Det-N-V parse. Two subjects had mean CSD times for the AN condition that were equal to or less than those for the DN condition.

Examining the materials analysis for a serial pattern, we find that only 5 out of 21 sentences had mean CSD times for the AV condition that were equal to or less than those for the DV condition. Also, 6 out of 21 sentences yielded CSD times for the AV condition that were equal to or less than their complementary DV version. The serial interpretation would predict that a majority of subjects or sentences of the AV condition would be as fast as the control (DV) in order to account for these data.

There is one more serial account that must be dismissed. It is a more complicated and less parsimonious serial representation of the data, namely, an unsystematic guessing strategy in which some subjects on some sentences use a Det-N-V serial parsing strategy and some subjects on some sentences use a Det-N-N serial parsing strategy. That is, the same subject can apply both serial parses and the same stimulus sentence can induce either serial parse. In other words, there will be some very fast CSD times for the ambiguous versions (comparable to times for the disambiguated versions) for some

subjects and sentences, but other times will be much slower when subjects (arbitrarily) choose the wrong parse and garden-path. However, when these are all averaged, the resulting means for the ambiguous conditions will be longer than the disambiguated versions. In order to test this theory, we must calculate the variances for the raw data for each of the conditions for each subject and each sentence, for it is expected that a guessing strategy would increase the variance greatly in the ambiguous conditions as compared to the disambiguated controls.

The results are unequivocal. The variance for the AV condition is not significantly different from either of the disambiguated versions: $F(101,92)=1.00$ with DV and $F(93,92)=1.3$ for the DN condition. However, again, the AN condition had significantly greater variance than the DN condition: $F(95,93)=2.18$, $p<.02$. The serial account of these data would demand that, at least, the AV condition would show a higher variance, reflecting the highly variable CSD times caused by the guessing strategy. This was not the case.

The significantly greater variance of the AN condition can, nonetheless, be explained in another way. Recall that, in both the AN and AV conditions, a delay is implemented by the parser until the POD, at which point the work required to attach the CA into the current parse structure is performed. However, there is an extra, garden-path effect inherent in the CSD times for the AN materials. Not only does the CA have to be parsed in the AN condition, but it is also necessary to reassign the head noun at the POD. This is not the case in the AV condition, where the initial head noun assignment is correct. The consequence of the misanalysis of the head noun for the AN stimuli is that the CSD

times for this condition show more variance among subjects and materials in recovering from the garden-path.

Turning now to the error rates, we see that they also support the delay model for these materials. The errors follow the same pattern as the decision times with higher rates at the POD, where processing begins, for both the ambiguous versions. In addition, higher rates at the first noun in the DN condition suggest the difficulty the parser experiences in encountering a noun that cannot act as the head of the noun phrase.

Lexical bias was not a significant factor in the ambiguous region, a finding which is consistent with the post-hoc subject ratings test of Frazier and Rayner (1987), although a bias effect was observed in the later part of their sentences. That is, when the sentence resolved with the structural preference, the reading times for the remainder of the sentence were significantly faster. This implies either that lexical preference does not influence initial parsing of CA's or that there is only one lexical entry for these items and differential part of speech usage frequencies for these subentries do not affect their access and integration times. Frequency effects are expected in cases where more than one lexical entry exists and especially when the different entries have widely varying frequencies.

Because no bias effects were found either in the ambiguous region or at the POD, another ANOVA was computed using the same variables but for the position in the sentence after the POD. No bias effects were found to be significant in both the subjects and materials analysis which suggests that the effects observed in Experiment Ia are probably localized with processing returning to baseline soon after the POD. It is

concluded that in ambiguous contexts, parsing did not default to the lexically preferred (more frequent) alternative of the CA and then backtrack if incorrect. Rather the parser seems to wait for the ambiguity to be resolved syntactically.

Why was there no effect of lexical preference? Lexical preference might only be useful to the parser when the alternatives comprise separate entries in the lexicon. In the case of systematic ambiguity the alternatives might only be subentries. Or, perhaps lexical preference can only be used in parsing in a post-access checking procedure after syntactic category assignment has already occurred. This seems to be the case for subcategorization information, which becomes available to the parser later in analysis (Mitchell, 1987; Ferreira and Henderson, 1990).

In general, then, the syntactic decision results agree with Frazier and Rayner's (1987) eye-movement data, although somewhat different conclusions are drawn. The ambiguous determiner versions of the stimuli showed evidence of a delay parsing strategy while the previously disambiguated versions did not.

Because some studies (Ferreira and Henderson, 1990; Frazier and Rayner 1987) have exhibited effects of bias after the POD in the later part of the sentence, it was thought that the lack of a bias effect in Experiment Ia might be due to the inability of the CSD task to detect late processes and that a post-sentential response task would possibly allow the bias effect to emerge if it takes time to have an effect. Rapid serial visual presentation (RSVP), introduced by Forster in 1970, is just such a task. In this paradigm, a sentence is presented one word at a time at a more accelerated pace than normal reading. This serves to limit the amount of exposure to the items in the sentence. If used in

conjunction with a post-sentential recall task, it is possible to examine how this time restriction affects the behavior of the parser, the prediction being that items that are syntactically more complex will show poorer recall.

More to the point in terms of the bias factor, it is expected that a degraded input will cause the HSPM to rely more heavily on other sources of information (e.g., lexical bias) in order to decode the stimulus. Speeded presentation is one method of degrading the stimulus, thus, lexical bias might emerge as a significant factor in the RSVP task. Also, as mentioned above, the post-sentential response in RSVP should give ample time for even a late-emerging effect.

Besides examining the data for a bias effect, the RSVP task might be able to uncover evidence that the parser assigns the first noun as the head of the noun phrase, similar to what was found in Experiment Ia at the first noun for the DN condition. In an RSVP task, Forster reported that adjectives and adverbs were less likely to be recalled than other words. Also, Mehler, Segui, Pittet and Barriere (1978) have found, using an RSVP paradigm, that adjectives that modify nouns are less likely to be recalled than those that are predicate adjectives. This taken together with the finding of Wright and Garrett (1984), that adjectives that are not heads of phrases do not show a syntactic context facilitation, would suggest that recall for the first noun when it does not function as the head noun will be worse (DN and AN conditions) than when it is the head noun (DV and AV conditions).

Experiment Ib

Rapid Serial Visual Presentation with Immediate Recall

Method

Subjects

Twenty-eight native English speaking Hunter College students served as subjects in this experiment. None had participated in the previous experiment.

Materials

The materials consisted of 30 sentence frames. In ten of these, the ambiguous word had a noun lexical bias (mean N/V ratio 83:17, with a minimum of 74:26), ten had an ambiguous word with a verb lexical bias (mean N/V ratio 18:82, with a maximum of 37:63), and ten had no lexical bias (mean N/V bias 51:49, with a maximum ratio of 62:38). These included materials from Experiment Ia. Each of the sentence frames had four version as in Experiment Ia. All versions of each sentence were identical up until the POD except for the type of determiner. This resulted in a design with the repeated measures variable of subjects crossed with lexical bias, syntactic context ambiguity, part of speech resolution, and word position. When sentences were the repeated measures variable, they were nested in lexical bias and crossed with syntactic context ambiguity, part of speech resolution, and word position.

Subjects saw some examples of each sentence type, but never more than one version from a particular sentence set. The experimental stimuli were intermixed with 24 two-clause sentence fillers which were stimuli from another experiment. All experimental and

filler items are presented in the Appendix.

Procedure

A rapid serial visual presentation (RSVP) task was used. Each sentence was presented, one word at a time, in rapid succession on an IBM AT microcomputer. Words were presented at the center of the screen, inside a box, with each new word replacing the last one. Subjects were instructed to press the enter key after they received the ready pattern signaling the beginning of the next sentence. Subjects, who were tested individually, sat at a computer console and silently read instructions displayed on the screen while the experimenter read them aloud. The instructions were as follows:

> This is an experiment about perception and sentence memory. You will see sentences presented one word at a time on the screen. Each word will appear in the center of a small window. As each word appears, it will erase the preceding word. You will have to watch very carefully in order to see all the words.
>
> Each sentence will begin with the word "READY" at the center of the window. The "READY" signal will be replaced by a block pattern. This pattern will then be replaced by the first word of the sentence, followed by the rest of the sentence, one word at a time. The same pattern will appear at the end of each sentence. After the entire sentence is presented, the screen will go blank, and you should say aloud as much of the sentence as you can. After saying the sentence, you will be prompted to press the ENTER key to continue. After a short pause, the next sentence will be presented.
>
> In order to acquaint you with the task, we will start with several practice sentences.
>
> If you have any questions, please ask the experimenter before going on.
>
> Press any key when you are ready to begin the practice trials.

After reading through the instructions, subjects were given twenty practice trials, during which the experimenter attempted to adjust the presentation rate to achieve recall ranging from 70%-80% correct. For most subjects, the presentation rate used in the experiment was either 83 or 100 msec per word. After the presentation of each sentence, subjects repeated it aloud. The subjects' verbatim recall responses were manually recorded by the experimenter, who was seated with her back to the subject in the same room. Additionally, the subjects' responses were recorded on cassette tape and later transcribed in order to check the accuracy of the initial written scoring.

After the twenty practice sentences, the subject was able to ask questions and then started the experimental trials. The entire experiment took subjects about 30 minutes.

Results

Two analyses of variance (ANOVAs) were used to analyze the data. In one, subjects, treated as a random effect, were crossed with part of speech resolution, syntactic context ambiguity, lexical bias (noun, verb or even), and word position (four locations in the sentence). Position 1 was the determiner, position 2 was the first noun, position 3 was the categorially ambiguous word, and position 4 was the POD. In the other analysis, materials (the random effect) were nested in bias but crossed with all other fixed variables.

The grand mean percent recall error was 38. The only main effect was for word position, which was highly significant in both the materials and subjects analyses: $F_1(3,81) = 10.45$, $p<.0001$ and $F_2(3,81) = 14.12$, $p<.0001$. Three interactions were also

significant. Part of speech resolution by word position was significant: F_1 (3,81) = 17.97, p<.0001 and F_2 (3,81) = 22.47, p<.0001, with the noun resolution stimuli showing much better recall at the POD. A better representation of what is causing these effects can be seen in a further division of these data by type of ambiguity, which reveals a three-way interaction of syntactic context ambiguity by part of speech by word position: F_1 (3,81) = 3.3, p<.05 and F_2 (3,81) = 2.74, p<.05, Figure 6. Here, at the position of the first noun, recall for the DV stimuli is best and for DN the worst. The ambiguous versions group together at this position, in the middle, being significantly better than DN but worse than DV.

At position 3, the categorially ambiguous word, the AV stimuli are recalled better than the AN stimuli. This must be attributed to a retrograde effect (an effect of subsequent material on prior material) as these two conditions do not differ in materials until the POD. Again, at the POD, the verb resolution stimuli are recalled significantly worse than those with a noun resolution.

The other interaction that was significant was lexical bias by part of speech resolution by position: F_1 (6,81) = 4.68, p<.001 and F_2 (6,162) = 4.25, p<.001. Because this interaction shows a very complex picture, the even bias condition has been left out of Figure 7. Note that this interaction collapses across syntactic context ambiguity (ambiguous and disambiguated versions). The main cause of the interaction might be summarized as being induced by the effect of a noun bias on a noun resolution (NN line) compared with the case of a noun bias and a verb resolution (VN line).

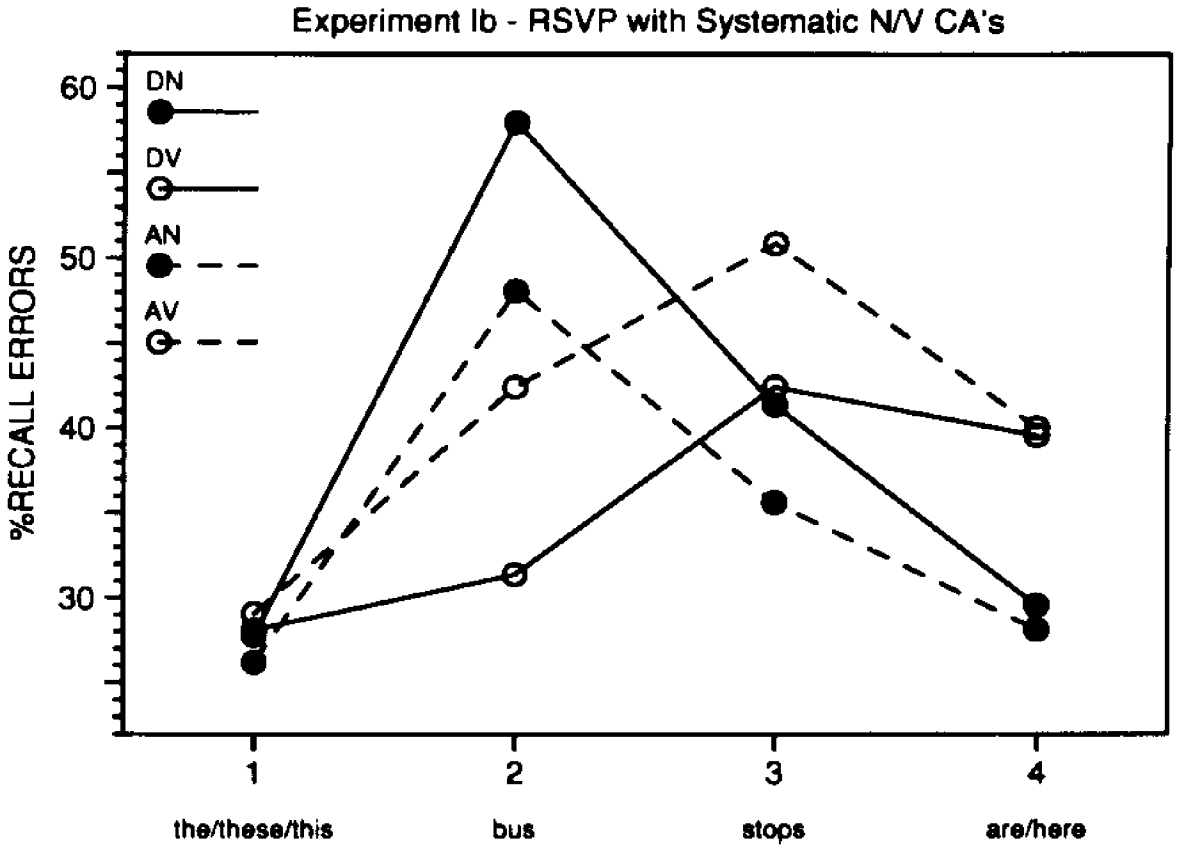

Figure 6. Experiment Ib - RSVP % Correct Recall as a function of syntactic context ambiguity, part of speech resolution and position in sentence.

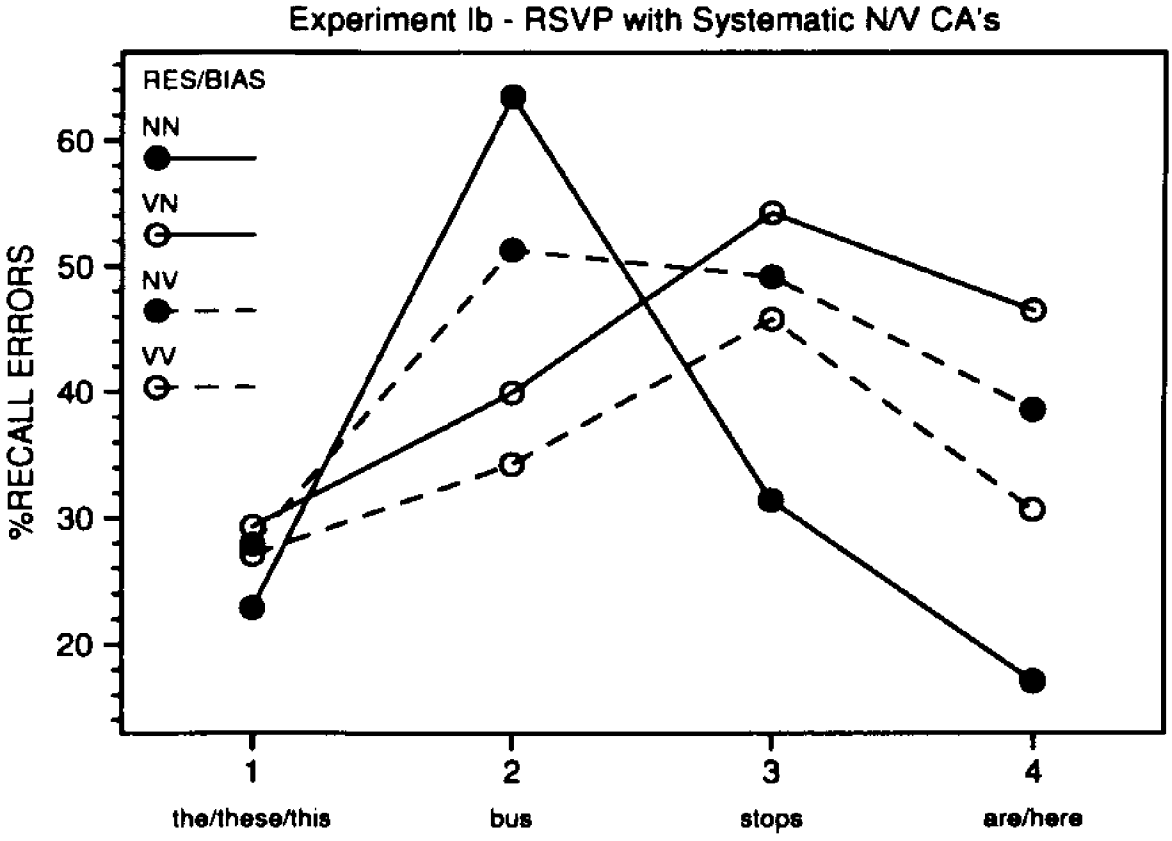

Figure 7. Experiment Ib - RSVP % Correct Recall as a function of lexical bias, part of speech resolution and position in sentence.

Discussion

The significant effects at position 2 (first noun) for the noun resolution stimuli strengthen the previous findings by other researchers that (1) noun-noun compounds are difficult to process in RSVP when the first noun is the possible head of the noun phrase (Kroll and Potter, 1984), and (2) adjectives in adjective-noun constructions are recalled worse when they are ambiguous with respect to whether they modify the noun or form a compound with it (Dommergues et al., 1979).

In addition, Mehler, et al. have reported that adjectives that precede and modify nouns are recalled worse than when they are part of a predicate following the noun. This is one explanation for why the DN stimuli fare worse at position 2, which is for this condition the "modifying noun." This position is recalled fairly well in the DV condition, suggesting that when the first noun assumes the role of the head noun it is more easily recalled than when it does not. In addition, it may be that DV is significantly better here than for the other conditions because the parser took the right path based on the disambiguating determiner and the syntactically preferred parse (Determiner-Noun-Verb).

A second, related, reason for the difficulty at position 2 for the DN condition is that this memory trace was lost as a result of interference and heavier resources being allocated here because of the attempt to assign this noun as the head noun and then having to assign it to the next incoming noun instead. In other words, the DN condition is significantly worse than the others due to the misanalysis of this noun as the head.

Another reason for the difference at position 2 might be that recall is inhibited for the first noun in the DN condition because it follows a plural determiner and therefore

disagrees in number. That is, when the subject attempts to reconstruct the sentence for recall, there may be a response bias against recalling the singular noun because it is locally ungrammatical.

The significant difference at position 3 (the CA) for the AV vs. AN stimuli indicates differential parsing. Interestingly, this must be a retrograde effect as these two sentence versions do not differ until the POD. The better recall for the AN stimuli could reflect the easier processing of the next word and/or the fact that position 3 served as the head noun in this condition.

The significantly better recall for noun resolution stimuli at the POD is somewhat puzzling. It was thought that this could reflect a lexical effect as the DN and AN sentences contained a high frequency verb at this position (often a form of *be*). Although the mean frequency for the words at this position was extremely high, that for the verb resolution stimuli was much higher (25483 vs. 3706 for the verb and noun resolution, respectively) due to the occurrence of the word *the* (FK frequency of 69975) in six of the eighteen continuations after the main verb.

What, then, can account for this difference between the noun and verb resolutions at the POD? One factor might be that although the mean frequency was lower for the noun resolution stimuli, thirteen out of the eighteen sentences continued with the most frequent word (*are* FK frequency of 4372), whereas only 6 of the eighteen verb resolution sentences continued with *the*. It may be that there is a ceiling effect of frequency operating here. Therefore, the noun resolution sentences had thirteen very high frequency continuations out of eighteen times, while the verb resolution sentences only had eight out

of eighteen (6 *the*'s and two others). The other possibility is that this effect reflects the difference between obligatory vs. optional constituents. Since in the noun resolutions, the word at the POD was always a verb and, in fact, the main verb of the sentence, it was recalled better relative to the parts of speech at the POD that follow the main verb in the verb resolution sentences.

Finally, a bias effect was found using this methodology. The bias by part of speech by position interaction (Figure 7) shows poor recall of position 2 in the noun resolution materials with noun biased CA's. Again, this must be a retrograde effect because bias was not a factor until position 3, at the CA. The poor recall here for noun resolution stimuli with a noun bias can also be explained by a "head of phrase" strategy. In the noun resolution case, the first noun is taken as the head noun which results in an incorrect parse. The relatively good recall for these noun bias stimuli at positions 3 and 4 suggests that the recovery from this misanalysis is aided by the noun bias of the CA. In fact, this seems to cause the system to drop the first misassigned noun (position 2) like a "hot potato."

In contrast, compare the poor recall at position 3 of the verb resolution stimuli with a noun biased CA (VN condition). It appears that the noun bias interferes with the syntactic requirement to parse the CA as a verb. This can be contrasted with the verb biased, verb resolution stimuli (VV), which fare better at this position.

Here, then, we have some evidence for a later lexical bias effect in RSVP, one that is, in fact, retrograde. It also becomes clear from examining the results from this RSVP task that several different processes are surfacing. There is a possible lexical frequency

effect at the POD for noun vs. verb resolution stimuli (*are/here*). There is a retrograde effect attributed to both syntactic context (AN vs. AV at position 3) and lexical bias (noun resolution vs. verb resolution for noun bias items at position 2 and 3). And, the effect of syntactic context ambiguity at position 2 could be considered to arise from on-line processing inasmuch as it mirrors the CSD measure of Experiment Ia. These factors make it difficult to interpret the RSVP data and indicate the importance of using other paradigms which allow for the examination of events occurring earlier in the processing. The naming task in Experiment II was applied to similar stimuli for this reason. However, there is still a methodological problem here concerning the data from Experiment I that must be addressed.

Frazier and Rayner had some concerns that their conclusions of a delay strategy could be disputed because they had not manipulated bias directly in their stimuli. The delay strategy they describe is considered to use a multiple access, nonselective mechanism. In fact, in order for the parser to engage a delay strategy, it must be aware that there is an ambiguity, i.e., that there is more than one reading for the ambiguous word and this would not be the case if selective access had occurred.

Frazier and Rayner, therefore, had to examine their data for evidence of another possible strategy in the resolution of CA's, that of semantic preference (Milne, 1982), a selective access strategy. In this strategy, the differential semantic plausibility of the alternative structures determines the initial assignment of the categorially ambiguous item. The semantic preference account predicts that there will be some processing interference when the CA is syntactically resolved opposite to the preference of the ambiguous phrase.

Frazier and Rayner obtained preference ratings in a sentence completion task for their categorially ambiguous stimuli. Subjects were presented with the beginning of each of the experimental sentences up through the CA. For their Experiment I stimuli, 8 sentences were completed more often as Noun-Verb and 8 as Noun-Noun constructions. For Experiment II stimuli, the numbers were 7 and 9. In post hoc analyses using these preference ratings, no support was found for the semantic preference account in their data.

The present experiment was designed to circumvent this criticism in two ways: (1) the stimuli are systematic with regard to their meaning which would limit the use of a strategy that depends on semantic variables, and (2) lexical biases of the ambiguous words (as reported in FK, 1982) were systematically manipulated so that this variable could be included in the statistical analysis to measure directly whether bias differentially affected parsing.

However, there is still the possibility that a higher level of plausibility (for the whole phrase) could have a different preference than that of the single word. For example, although the word *flowers* has a noun bias, when perceived in the context of the phrase *the tree flowers*, it might be more often parsed as a verb. In order to test whether single word biases from FK were, in fact, correct for these particular phrases, a sentence completion task was performed on three-word sequences that comprised the ambiguous regions in the test items (e.g., *the bus stops*). In addition, completions were collected for the ambiguous word alone to compare these results to those of the FK frequency counts.

This experiment, then, provides both semantic and lexical preference ratings. The semantic preference rating is a measure of how the item is perceived in a given semantic

context. The lexical preference rating is a measure of how the word is used independent of context.

In addition, this experiment allows the examination of whether different factors govern usage for words in isolation vs. words in partial sentential context.

Experiment Ic

Completions

Method

Subjects

Twenty-six Baruch College undergraduates who were native speakers of English served as subjects in this experiment. All subjects were female and were students in an English literature course. Participation in the experiment was voluntary.

Materials

Two sets of stimuli were compiled. In one, the word condition, the list consisted of the categorially ambiguous words from the above experiments with an additional six (two for each of the three bias groups). In the phrase condition, the list consisted of the two words comprising the ambiguous phrase preceded by the ambiguous determiner *the*. For example, the word condition included the word *stops* and the corresponding completion in the phrase condition was *the bus stops*. This resulted in each list containing 36 words (12 from each bias group). All experimental items are presented in the Appendix.

Procedure

Subjects were tested as a group in a classroom at the beginning of class and were alternately assigned to the word and phrase conditions so that an equal number of students were in each group. After handing out the printed lists, the experimenter read the instructions on the cover page aloud which were as follows for the word condition:

> What is your native language? _____
>
> Instructions:
>
> Please use each word in a complete sentence. Try to make each sentence at least 5 words long. Work as quickly as you can.

For the phrase condition the instructions were changed to read:

> Please use each phrase in a complete sentence.

After reading the instructions, the experimenter informed the class that they would have a maximum of 15 minutes to complete all the sentences. Subjects were allowed to ask questions and then turned to the first page of completions to begin the task. After 15 minutes the experimenter told the subjects to stop writing and collected the sheets. Only those students that had indicated English as their native language were included in the analysis.

Predictions

Although the FK frequency counts are compiled from written text and as such might be construed as reflecting contextual bias, they are a summation across all contexts and

therefore, do not indicate how a CA will be used in any specific context. In effect, they constitute a general frequency count for the CA, which suggests something about the overall preference for these words. It is expected, then, that the word completions might be correlated better with the FK counts because this task might induce the subject to rely more heavily on inherent lexical preferences.

On the other hand, the phrase completions might also be correlated with the FK counts. This is because the phrase completion stimuli employ the ambiguous determiner *the*, which might induce subjects to depend on lexical biases when completing the phrase. This would be at odds with the evidence from Experiment I that the processing of CA's is not driven by lexical preferences.

Results

The completion data are presented in Table 2, which shows the percentage of noun completions by lexical bias for the word and phrase conditions.

For the Word completions, a Fisher Sign test showed that the noun bias items were used significantly more often as nouns than as verbs: $z=2.41$, $p<.05$. Both the verb and even bias items were equally likely to be used as verbs or nouns.

For the Phrase completions, a Fisher Sign test showed that the even bias items were used significantly more often as verbs than as nouns: $z=3.17$, $p<.01$. In addition, a Wilcoxon Signed-Ranks test showed that verb bias stimuli were more often used as verbs, $z=2.12$, $p<.05$. Noun bias words, however, were not used significantly more as nouns or verbs.

Table 2. Experiment Ic - Percent noun completion by lexical bias and task (Word and Phrase).

	Lexical Bias		
	Noun	Verb	Even
Word Completions	76%	39%	46%
Phrase Completions	38%	33%	24%

Correlations were also carried out as follows: the frequency of the noun form was added to that of the verb form from FK to get a total FK frequency for the word; the percent noun FK frequency was the FK frequency of the noun divided by the total FK frequency. This was correlated with the percent noun completion data from the experiment. For the Word condition, the Pearson correlation coefficient for percent noun FK frequency and percent noun completion was .70, $p < .005$. For the Phrase condition, r=.096 which was far from significant.

It is interesting to note that the pattern of completions changed from the word to phrase completions. In the word data, noun bias items were more often used as nouns in a sentence. However, in the phrase data, verb and even bias items were more likely used as verbs. In order to examine whether the two different tasks caused this differential usage of the noun or verb form in sentences, an ANOVA was also computed on these materials.

The grand mean percent noun usage was 42.7. The main effect of Completion task was significant: $F(1,33) = 13.67$, $p<.001$, with more noun completions given in the Word task.

The other significant main effect was for bias: $F(2,33) = 3.96$, $p<.05$. Overall, noun bias forms were used more often as nouns than were verb or even bias forms. The task by bias interaction was not significant in this analysis.

Because it was thought that the even bias data were masking an interaction between the noun and verb bias materials, a separate ANOVA was computed with only the noun bias and verb bias stimuli. Again, the main effect of completion task was significant:

$F(1,22) = 9.22$, $p<.01$ with more noun completions for the Word task. Bias was also a significant factor here: $F(1,22) = 5.14$, $p<.05$ reflecting the higher percentage of noun completions for noun bias items. In this analysis the interaction of task by bias is significant: $F(1,22) = 5.11$, $p<.05$. In the Word task, 76% of the noun bias items were completed as nouns, whereas in the Phrase task, this was true for only 38% of these same words.

Discussion

The results for the Word completions imply that the FK frequency counts are a good indicator of the subjects' lexical frequency representations as reflected in the completion patterns for words in isolation. However, the significant interaction in the ANOVA shows that the syntactic environment of a CA can affect how the word is interpreted. Here, the percent noun usage of noun bias words was significantly less in the Phrase completion task, suggesting that a syntactic preference strategy (determiner-noun-verb) is the default for syntactically ambiguous material in sentence context. This effectively rules out the application of a lexical preference (bias) strategy in these sentence constructions.

These results, then, demonstrate that the FK frequencies for part of speech biases reliably reflect subject ratings when the word is presented in isolation. And, since differential usage was obtained depending on completion task, they suggest that lexical bias alone does not determine how a CA is perceived. Syntactic environment also affects this perception.

Recall that Frazier and Rayner also ran a completion experiment in order to perform

post-hoc analyses of bias. However, there might be a problem with the interpretation of the preferences they obtained for their stimuli. It turns out that the phrases for which an Adjective-Noun (here, referred to as Noun-Noun) reading was preferred contained a CA with a dominant noun reading with the mean FK frequencies being 94 and 17 for the noun and verb alternate readings of the CA's in this group, respectively. For example, one phrase that was completed as A-N 96% of the time contained the CA *surface* whose noun form frequency is 221 compared to its verb form frequency of 1.

Conversely, for the group of phrases that was completed most often as Noun-Verb, the mean FK frequencies for the noun reading was 41 versus a mean of 64 for the verb reading. These, therefore, were a much more equibiased set. This result is in agreement with the current data which suggest that even bias items are completed as verbs when the syntactic environment is ambiguous.

Because the FK frequencies were not a good predictor of the completions in the phrase condition here, there was an attempt to regroup the stimulus sentences from Experiment IA into bias groups ranked in the Phrase completion condition in order to test whether these ratings would show a bias effect. Unfortunately, for only three of the twenty-one phrases was the N-N reading preferred. This is hardly a sufficient number on which speculate.

One final point can be made with regard to the bias factor of Frazier and Rayner's data. They argued that because the first word in the ambiguous region occurred most often as a noun (as opposed to a derivative usage as an adjective), a lexical preference account would predict that this word would be most often parsed as the noun of the

sentence, and, consequently, the next word (the CA) would be parsed as a verb. This would result more often in an initial N-V parse for both the AN and AV conditions, but would be incorrect only for the AN stimuli. Since they observed an increase in reading times for both ambiguous types of materials at the POD, they concluded that the lexical preference account was not viable.

This is not the position that is taken here. The present experiment assumes that there is no categorial ambiguity in the first noun, but only regarding its status as the head of the phrase. Therefore, it is only the lexical bias of the CA that is at issue and the completion data serve best to demonstrate that given a syntactically ambiguous context (determiner *the*), subjects will opt for the N-V over the N-N parse.

As previously mentioned, the importance of employing different paradigms in order to observe lexical and parsing effects at various times in sentence processing necessitates yet another task be used to examine categorially ambiguous words, specifically one that taps the lexical access process. Naming has been purported to be such a task.

In particular, the influence of contextual information has been found to depend on the nature of the task used. Lexical decision (or other post-access decision tasks) and naming have become two necessary converging operations that should be considered in any evaluation of context effects because they seem to be differentially sensitive to pre-and postlexical influences (Forster, 1979; Seidenberg, et al., 1984; Stanovich and West, 1986). Lexical decision is assumed to require a post-access decision stage. Naming is considered free from post-access effects because it does not entail a decision. As mentioned previously, data from eye-movement studies such as Frazier and Rayner's (1987) do not

discriminate among the different reading comprehension processes (perceptual, retrieval and integration) and are, therefore, not sufficient to answer questions about the lexical access process.

In short, effects obtained with lexical decision, but not naming, tasks are postlexical effects and those obtained with both tasks are considered lexical effects. Therefore, it is crucial to include a naming task along with other post-lexical tasks (e.g., SPVP CSD and RSVP) if one is interested in addressing questions of lexical access.

Experiment II was proposed so that naming latencies could be obtained and compared to those results from the previous experiments. For these experiments, new stimuli were constructed that incorporated CA's having two distinct pronunciations corresponding to their different parts of speech (e.g., *house* has two distinct pronunciations, one noun and the other verb).

Experiment II

Looking at Categorial Ambiguities Using the Naming Task

The previous experiments provide some insight into how systematic CA's are parsed but still leave open the question of whether lexical bias can affect category assignment. A bias effect was obtained in the RSVP task but no bias effect was seen with CSD. This might be because lexical bias can only be taken advantage of in a post-checking procedure after category assignment has been made and this can best be seen as a retrograde effect in the post-sentential recall task of RSVP. Conversely, the bias effects

seen in the RSVP study could be attributed to another cause. The rapid presentation of the material might induce the parser to rely more heavily on other sources of information (e.g., lexical bias) to structure the input.

Again, as stated in the LP hypothesis, perhaps the default parsing strategy in a syntactically ambiguous environment is to assign the higher frequency category to the categorially ambiguous word. However, it is possible that the different senses of homographs like systematic CA's share one lexical entry and whether or not bias effects can be observed to function within lexical entries is another question to be addressed.

Therefore, to further investigate where, if at all, lexical bias can have an effect on parsing CA's, a naming task was employed. If, in fact, lexical bias is a factor in the access of CA's, then subjects should, when forced to make a selection in a syntactically ambiguous environment, more often give the preferred pronunciation (higher frequency form) for these stimuli, presumably because the LP (default) strategy would be to access the higher frequency alternative first.

In lexical priming studies in which the homographs have different meanings, it is possible to indirectly detect which alternatives have been activated by presenting synonyms of the alternate readings of the homograph to subjects for, for example, lexical decision (as in the cross-modal priming studies). This type of paradigm becomes more difficult to implement, however, when the stimuli vary minimally semantically. But, by using stimuli that have different pronunciations for the noun and verb alternatives in a naming task, it becomes clear which version has been accessed by the subjects.

In addition, it is always preferable to use a word as its own control. As Rayner and

Frazier (1989) have pointed out, it remains unclear what is the appropriate control for the frequency of homographs, e.g., one that matches the frequency of the subordinate or dominant meaning or the combined frequency of all the alternate forms. This is one advantage of this technique over lexical priming studies.

In order to obtain naming data, stimuli similar in form to those of Experiment I were constructed. However, since it was imperative to know which category was assigned to the ambiguous word, these stimuli had distinct pronunciations for the noun and verb forms (e.g., the homograph *graduate*). This rendered the subjects' responses transparent with regard to which form they had accessed.

In addition, the nature of this design allows a test of the modularity theory (Fodor, 1985), which states that separate modules of the parsing system operate independently and that these modules are informationally encapsulated. If prior disambiguating information can restrict lexical access to the syntactically appropriate entry, then more appropriate pronunciations should be observed in the disambiguated control sentences compared to the syntactically ambiguous ones. Also, since it has been found that naming of ungrammatical words is slowed relative to those that are in grammatical agreement with the context (Motley et al. , 1981; West and Stanovich, 1986), then it might also be found that correct naming times are faster, the incorrect pronunciations being ungrammatical. Such results would suggest that syntactic context can affect the lexical access of CA's, which would be evidence against modularity. Therefore, the purpose of conducting this study was to use the same variables as previously, but to look at an earlier time in the processing, potentially at lexical access.

Before embedding these stimuli in sentences, naming times were obtained for the CA's in isolation. This provided a baseline control to compare against the same words used in a manipulated syntactic environment. Note that in the previous Experiment Ic there was a difference in how subjects completed items depending on whether they were presented in isolation or embedded in a syntactically ambiguous phrase.

The naming task is a more direct measure of lexical preferences because, unlike the sentence completions in Experiment Ic which require conscious semantic and syntactic processing, naming times are considered to be strictly lexical. However, the existence of two pronunciations necessitates making a selection in this naming task.

Experiment IIa

Naming in Isolation

Method

Subjects

Twenty-nine native English speaking Hunter College students served as subjects in this experiment. None had participated in the previous experiments. Some subjects were offered extra credit points for participating and others volunteered without compensation.

Materials

The materials consisted of 46 experimental words. Thirteen of these had a noun lexical bias (mean N/V ratio 77:23), twenty-two had a verb lexical bias (mean N/V ratio 20:80), and eleven had no lexical bias (average N/V bias 51:49).

An attempt was made, as in the previous experimental materials, to choose ambiguities that were systematic. Each homograph had a different pronunciation for its noun and verb forms. The difference in pronunciation could be due solely to a segmental change (as in *excuse*) or include changes in stress and syllabification (as in *record*).

The 46 experimental items were intermixed with twenty-six fillers having single pronunciations. All experimental and filler items are presented in the Appendix. The primary reason for including so few fillers was that, in pilot studies, almost from the beginning of the experiment, subjects reported being conscious of the fact that some items had two pronunciations. It was decided that an unacceptably large number of fillers would have to be added to alter this perception. Therefore, in the interest of constraining the number of stimuli, only thirty fillers were added.

All subjects saw all items but each received a different random presentation sequence to guard against order effects as it is possible to get into a noun or verb pronunciation "rhythm" since many of the differences involved stress changes.

Procedure

Subjects, who were tested individually, sat at a computer and wore a small lapel microphone which was adjusted to the level of each subject's voice so that a voice-activated switch would trigger on a pronunciation but not with random background noise or physical movements of the subject. Words were presented at the center of the screen and remained on the screen until the microphone was triggered, which caused the screen to be cleared.

After being seated, subjects were instructed to read silently the instructions displayed

on the screen while the experimenter read them aloud. The instructions were as follows:

> This is a pronunciation experiment. You will be presented with words one at a time on the screen. As soon as you see the word, pronounce it out loud as quickly as you can. The word will stay on the screen until the computer has detected your pronunciation. If the word remains on the screen after you have pronounced it, pronounce it again.
>
> There will be 10 practice trials so that you can learn the task.
>
> Remember, the microphone is very sensitive so please try to be quiet while you are working.
>
> If you have any questions at this time please ask the experimenter. You will have another opportunity to ask questions again at the end of the practice trials.

After reading through the instructions, subjects were given ten practice trials, during which the experimenter adjusted the microphone sensitivity. After practice, the subject was allowed to ask questions and then started the experimental trials. The entire experiment took subjects about 15 minutes. Reaction times representing the time interval from word presentation to initiation of pronunciation were collected and the responses were recorded on tape to be scored later as noun or verb pronunciations and to identify procedural errors.

Prior to data analysis, any reaction times that were less than 50msec were discarded as mistriggers. Pronunciation times greater than two standard deviations above or below the mean for each subject were replaced with the value for exactly two standard deviations above or below the mean for that subject. False starts and undetected

pronunciations, as scored on the tape, were also marked as pronunciation errors.

Predictions

In a syntactically impoverished environment, it is expected that the preferred usage (higher frequency part of speech) will be the pronunciation given most often as the subject has no other basis on which to make a selection between the two alternate forms unless, of course, s/he acts arbitrarily. Another prediction might be that naming times for the dominant form would be faster because they would be activated first due to their higher frequency if, in fact, lexical representations are frequency ordered.

Results

The pronunciation data are presented in Table 3 for each lexical bias type. Fisher Sign tests for correlated samples were used to investigate whether lexical bias affected which pronunciation (noun or verb form) was given. Percent noun pronunciation was first calculated for each of the items (see method in Ic). For the noun bias items, $z=2.18$, $p<.05$, with significantly more items being pronounced as nouns than as verbs. Similarly, verb bias items were pronounced significantly more often as verbs than nouns; $z=2.5$, $p<.05$. The even bias items were equally likely to be pronounced as verbs or nouns, $z=.60$.

An ANOVA was calculated with the design including the fixed variable lexical bias (noun, verb or even) and subjects as the random repeated measures variable. The dependent variable, percent noun pronunciation, had a grand mean of 51. There was a highly significant main effect of bias, $F=42.42$, $p<.0001$. The percent noun pronunciation

Table 3. Experiment IIa - Naming reaction times (msec) in isolation for Noun and Verb pronunciations by lexical bias (percent noun pronunciation in parentheses).

		Pronunciation	
		Noun	Verb
Noun Bias	(67%)	700	705
Verb Bias	(34%)	715	732
Even Bias	(48%)	687	755

for noun bias items was 65, while that for verb bias items was 32.5. Even bias items were pronounced as nouns 56% of the time.

Correlations were also run on percent noun pronunciations with FK percent noun frequencies (see Experiment Ic above, which uses an analogous procedure), $r=.51$, $p<.005$. Like the Word completion data above, it appears that the FK part of speech frequencies are a reliable estimate of pronunciation category for words in isolation.

A subject ANOVA on the pronunciation reaction times was also computed with the fixed variables of bias (noun, verb and even) and pronunciation (noun or verb) and the random repeated measures variable of subjects. The grand mean naming time was 716 msec. The main effect of pronunciation was significant, $F=5.85$, $p<.02$, with noun pronunciations being given faster than those for verbs (701 vs. 731 msec).

This effect on pronunciation time was accounted for by the pronunciation by bias interaction which was also significant: $F=4.33$, $p<.02$, with the only significant naming time differences being between the noun (687 msec) and verb (755 msec) pronunciations for the even bias materials. The naming times for the noun and verb bias materials did not differ depending on the pronunciation given. In fact, in a further analysis of identical design but which included only the noun and verb biases items, there was no significant interaction of pronunciation by bias.

In addition, an item ANOVA was computed for the reaction time data for each bias group separately as there were unequal n's among bias groups. Reaction times were not significantly different for the verb or noun pronunciations for any of the three bias groups.

Since no variables were found to significantly affect reaction time in both subject and

materials ANOVAs, correlations of naming time with word frequency were computed in order to ensure that the experimental apparatus was, indeed, sensitive to subjects' responses. It was expected that there would be a negative correlation between reaction time and log frequency, as has been found in numerous other studies (Forster, 1979). Over all stimuli, the Pearson correlation coefficient for all the stimuli with the log of their total frequencies from FK was -.35, which was marginally significant ($r>.369$ for $p<.05$). When divided into bias groups, the verb bias items were significantly negatively correlated with their log frequency, $r=-.69$, $p<.02$, while the noun and even bias items were not. This is indirect evidence that, at least for some stimuli, the pronunciation times reflected some level of lexical processing.

Discussion

Taken together, these results suggest, again, that the FK frequencies which were used to choose bias groups, are a good predictor of which pronunciation will be given in isolation. Pronunciation preferences were in the direction of bias and were highly correlated with the Francis and Kucera percentages. This also suggests that CA's are organized in the mental lexicon in such a way that differential frequency is represented and is made available at or immediately after lexical access, at least in this task.

However, the fact that there were no significant effects involving naming reaction times is also telling. One possible explanation is that CA's that do not vary semantically share one main entry in the lexicon with the alternate readings being listed by frequency as subentries. One consequence of this for lexical access is that it should take the same

time to retrieve either one. If the items within the entry are listed by frequency, then a reaction time effect due to this factor might be obtained but the "distance to travel" between subentries might not require enough time to be experimentally detectable. However, this frequency listing could still be used as a selection criterion for which pronunciation to generate, as was hypothesized above. The question of the form of the lexical entry for systematic homographs will be further addressed in the General Discussion section.

The follow-up experiment to the previous one was to take the same stimuli and embed them in sentence constructions analogous to those of Experiment I, still employing the naming task. In this way, it is possible to ask some of the same questions about parsing effects and lexical retrieval in sentence processing while looking at the earlier stage of access. Specifically, we will then be able to ask "Does previously disambiguating syntactic context result in syntactically appropriate lexical access?" Also, the question of whether frequency dominance still affects access in a sentential environment and whether it interacts with syntactic context can be addressed. These results, then, will be able to be interpreted in terms of lexical effects as opposed to those of Experiment I in which only postlexical effects could be inferred.

Experiment IIb

Subject-Paced Visual Presentation with Naming at the Ambiguous Word

Method

Subjects

Twenty-four Hunter College undergraduates who were native speakers of English served as subjects in this experiment. Participation in the experiment was offered as one means to obtain extra credit points in a Psychology course.

Materials

The materials consisted of 18 sentence frames which were constructed using a subset of the stimuli from Experiment IIa. These sentences were identical in structure to those in Experiment I, except that the CA had different pronunciations for the noun and verb forms. Nine of the sentences contained noun bias ambiguous words and nine contained verb bias ones.

Whereas before, each sentence had four versions, in this experiment each sentence had only three. This is because the naming occurred at the ambiguous word, before the POD, so there was no distinction in these materials between the two ambiguous versions. In the disambiguated construction, it was clear how the CA would be resolved from the previously presented determiner (*these, a*). However, in the ambiguous construction (using the determiner *the*), the ambiguous word was not disambiguated until the POD, which came after the naming. Therefore, although there were two versions of the unambiguous construction (noun and verb disambiguations), there was only one ambiguous version for the purposes of data analysis up through the position of the CA. However, five out of the nine noun bias ambiguous sentences were resolved in the noun direction at the POD after the naming, as were five out of the nine verb bias ones. All

three versions of each sentence were identical up until the POD except for the type of determiner. An example stimulus set follows (CA in italics):

(27a) In class the professor announced that these schedule *conflicts* can

(27b) In class the professor announced that a schedule *conflicts* with

(27c) In class the professor announced that the schedule *conflicts* with/can

Version (a) is the disambiguated noun resolution condition (DN), (b) is the disambiguated verb resolution condition (DV), and (c) is the ambiguous version (AA). Subjects saw examples of each sentence type, but never more than one version from a particular sentence set.

The experimental stimuli were intermixed with 53 filler items with a variety of lengths and structures. All experimental and filler items are presented in the Appendix.

Procedure

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

> This is an experiment in sentence processing. You will be presented with sentences or sentence fragments one word at a time on the screen. After you read each word press the + key on the number pad to get the next word. Make sure you understand the sentence so far before going to the next word.
>
> If a word is printed in blue, pronounce it out loud as quickly as you can. The word will stay on the screen until the computer has picked up your pronunciation. Sometimes there will be a question after a sentence. Answer the question out loud. There will be 10 practice trials so that you can learn the task. The microphone is

very sensitive. Please try to be quiet while you are reading.

If you have any questions at this time please ask the experimenter. You will be able to ask questions again at the end of the practice trials.

When ready to continue, the subject pressed the enter key and practice trials immediately followed. During the practice trials, the experimenter stood beside the subject correcting procedural errors. After ten practice sentences, the subject was left to complete the assignment at his or her own pace.

The subject-paced, serial presentation of stimuli consisted of a single word at a time being printed in the middle of the screen in a box to help facilitate fixation. The word remained on the screen until the subject pressed the "+" key for the next word. When the subject pressed the "+" key, the word was erased and overwritten by the following word in the sentence which was also centrally displayed on the screen in the box. All words except those that were to be pronounced were printed in white on a black background. Words presented for pronunciation were printed in blue to cue the subject and stayed on the screen until the microphone sensed a triggering sound. This caused the word to be erased and the next word of the sentence to be printed in the box, at which point the subject was to continue with the reading task by hitting the "+" key for the next word. When the entire sequence of words for one stimulus sentence had been shown, the box disappeared briefly and was replaced with another one containing the "ready" signal for the next trial. Ten of the stimuli were followed by a question to which the subjects were to answer out loud.

The task, then, was an SPVP design with reading for comprehension except for the

pronunciation of the ambiguous word, which was color-cued. It was decided that using a more involved task than reading, such as CSD, in conjunction with naming would require too much of the subjects. Also, the main interest here was in collecting the naming data for the categorially ambiguous word.

The entire experiment took subjects about 20 to 30 minutes. All reading and pronunciation times were collected, and the pronunciations were recorded on tape for later pronunciation scoring. Also, answers to questions were recorded and checked to verify that subjects were reading for comprehension and not just pressing keys.

Prior to data analysis, naming times that were less than 50 msec were discarded as mistriggers. Pronunciation and reading times greater than two standard deviations above or below the mean for each subject were replaced with the value for exactly two standard deviations above or below the mean for that subject's pronunciation or reading times, respectively. False starts, as scored on the tape, were also marked as pronunciation errors.

Predictions

If LP is a strategy applied by the parser, it is expected that the preferred usage (higher frequency part of speech) will be the pronunciation given most often, at least in the syntactically ambiguous sentences where there is no syntactic context available that the parser can apply to help make a selection between the two pronunciations. If, however, the syntactic context influences naming, subjects should give the syntactically appropriate pronunciation more often in the disambiguated condition.

The syntactic context factor might also affect the pronunciation time, with

pronunciations for syntactically appropriate forms being facilitated due to their agreement with context. Conversely, pronunciation times for inappropriately named items may be slowed relative to baseline (naming times in isolation). These results could be attributed to output editing effects caused by syntactic agreement or disagreement with context.

Results

The data were divided into three classes for separate analysis. The first was the reading times for the three sentence positions *word before the determiner*, *determiner*, and *first noun*. The second data group consisted of naming times and pronunciation for the CA, and the third analysis was done on the reading times for the word after the ambiguous word, i.e., the POD.

Two ANOVA's were used to analyze the reading times for the first three positions. In one, subjects, the random repeated measures variable, were crossed with the fixed variables syntactic context ambiguity and word position. Position 1 was the word before the determiner, position 2 was the determiner and position 3 was the first noun. In the other analysis, materials was the random variable. Bias was not a factor in these analyses because it was not introduced until the target word for pronunciation. In fact, the stimulus sentences were identical across these positions except for the different determiners.

The main effect of word position was significant in both the materials and subjects analyses, with faster reading times at position 2 (the determiner): $F_1(2,34) = 6.07$, $p<.005$ and $F_2(2,46) = 4.8$, $p<.01$. These results are presented in Table 4. There was a

Table 4. Experiment IIb - Reading times (msec) in sentences by syntactic context ambiguity: three words preceding the categorially ambiguous word.

	Position in Sentence		
	Determiner-1	Determiner	First Noun
DN (these)	532	527	535
DV (this)	531	518	527
AA (the)	552	493	532

significant interaction of syntactic context ambiguity by word position only in the item analysis: $F_1(4,68) = 2.6$, $p<.05$, and this was due to a lexical effect, i.e., to the faster reading times for position 2 (the ambiguous determiner *the*) in the ambiguous (AA) condition.

Next, the naming data were analyzed by pronunciation (noun/verb) and naming times. Two ANOVAs were computed for the naming data. In one, subjects, the random repeated measures variable, were crossed with the fixed variables syntactic context ambiguity and lexical bias. In the other analysis, materials was the random variable.

Neither the subject nor the item ANOVA uncovered any significant main effects for ambiguity for the naming time data. The subject analysis did show a significant main effect of lexical bias: $F_2(1,23) = 6.27$, $p<.02$, with noun bias words pronounced faster than verb bias, but this was not significant in the item analysis.

An analysis that examined reaction time by pronunciation could not be computed because there were some items that were never pronounced as a noun and some that were never pronounced as a verb, which resulted in some missing data cells.

Item and subject ANOVAs were then calculated with the dependent variable being percent noun pronunciation with the fixed factors of syntactic context ambiguity and lexical bias. The grand mean percent noun pronunciation was 43.3. In both analyses, only the main effect of ambiguity was significant: $F_1 (2,32) = 31.64$, $p<.0001$ and $F_2 (2,46) = 36.64$, $p<.0001$, with the CA's in the DN sentences being pronounced as nouns 66% of the time, ones in the DV sentences pronounced as nouns only 31% of the time and AA items pronounced as nouns 33% of the time. There was no main effect of lexical

bias nor was there a significant interaction of lexical bias with syntactic context ambiguity. These results are reported in Table 5.

In addition to the above analyses, a Fisher sign test for pronunciation showed that the CA's in the DV and the AA sentences were pronounced as verbs significantly more often than as nouns (DV, $z=2.12$, $p<.05$ and AA, $z=2.12$, $p<.05$). Although 13 out of the 18 DN items were pronounced more often as nouns, this was not enough to reach significance ($z=1.5$, $p<.20$). However, recall that in the ANOVA above, DN items were found to be pronounced significantly more often as nouns than the DV or AA items were.

The final analysis for this experiment was an ANOVA with materials or subjects as the random effect and syntactic context ambiguity and lexical bias as fixed factors using the reading times for the position after naming (the POD) as the dependent variable. There was only one significant effect, that of the main effect for lexical bias: F_1 (1,16) = 5.84, $p<.05$ and, marginally, F_2 (1,23) = 3.71, $p<.06$, with the POD in the noun bias condition being read significantly more slowly than in the verb bias one (896 vs. 767 msec, respectively).

Discussion

It is clear, then, that pronunciation of CA's in a sentence context is not dependent on lexical bias, unlike the case for words in isolation (Experiment IIa), even in the condition with the ambiguous determiner *the*, in which no disambiguating syntactic context is available to the parser. This result is not surprising for the disambiguated sentences, in which the determiner serves to fully disambiguate the CA. In this case, the bias is of

Table 5. Experiment IIb - Naming reaction times (msec) in sentences by lexical bias and syntactic context ambiguity (percent noun pronunciation in parentheses).

	Sentence Condition		
	DN (these)	DV (this)	AA (the)
Noun Bias	690 (71%)	678 (32%)	677 (40%)
Verb Bias	732 (66%)	695 (29%)	701 (32%)

little or no assistance.

Consider that the parser is building a structure as it receives incoming items. In the disambiguated case, when the subject is asked to pronounce the CA, which in effect forces the subject to assign it a category since a pronunciation must be selected, the appropriate pronunciation is given. This is not necessarily to say that the state of the parser affects the initial lexical access of the appropriate choice. Remember that the naming task was employed here because it is presumably a task that reflects processes at lexical access. However, because there were no significant reaction time differences to pronounce the appropriate vs. inappropriate alternative (or between dominant and subordinate pronunciations in Experiment IIa), it might be assumed that there is only one lexical entry for a CA. Thus, when the entry is accessed, it becomes evident that there are multiple subentries among which a selection must be made. Indeed, this is the only way in which the parser can decide to implement a delay strategy, that is, if it receives more than one possible alternative from the lexical processor. It is possible that the parser can effect a choice, which would cause the selection of the syntactically appropriate alternative to occur significantly more often. This would, then, be considered a post-access selection mechanism, and not violate the modularity principle.

The time for this selection process might be expected to be reflected in the pronunciation times for the words in sentence context over and above that for the words in isolation, as it entails integrating the selections with the current context. However, the naming times in this experiment were similar to those reported in Experiment IIa where there was no syntactic context. In addition, the naming times for the ambiguous versions

were no faster than the disambiguated versions even though there was no biased syntactic context in which to integrate the different readings of the CA for the former. It seems that the selection mechanism was the same for both the disambiguated and the ambiguous items. Therefore, it could not have depended on syntactic context, per se, but perhaps a structural preference of the parser.

What does happen in the ambiguous case? Why would these words be pronounced more often as verbs but show no difference in pronunciation reaction time from the other conditions? Previously, in Experiment I, evidence was presented to support the delay strategy in parsing CA's in a syntactically ambiguous environment. If subjects are, in fact, delaying in the ambiguous case, it might be expected that they would give either equal numbers of noun and verb pronunciations or, if lexical bias has an effect, that this would affect their pronunciation, as was the case when the words were presented in isolation. Recall, however, that in the phrase completions of Experiment Ic which also used the ambiguous determiner *the*, 76% of the items were completed as verbs.

Since the selection is being forced at the ambiguous word, perhaps it occurs before the parser can initiate the delay process. After all, it is suggested that the parser will only use the delay strategy over a very short distance, as it is costly in terms of resources. It is possible that the parser begins to build (predict) a noun phrase as soon as it receives the ambiguous determiner and then assigns the next item as the head noun (Det-Headnoun). It is only after the CA is accessed that the potential dilemma in the parse is realized.

If there is a choice forced at access (as there is in the naming task), before the parser

has the opportunity to implement a delay strategy, the current state of the parse would be analogous to that for the DV stimuli (i.e., Det-Headnoun). Therefore, the pronunciation selection could be based on the prevailing parse. This would explain why the pronunciation pattern for the AA sentences looks much the same as that for the DV ones.

It is interesting to note that the ambiguous noun resolution stimuli showed longer syntactic decision times at the POD than the ambiguous verb resolution stimuli in Experiment Ia. Again, this could be the result of having a default syntactically preferred parse construction in place and delaying the CA assignment until the POD. Here, the verb assignment would take less time because it would fit the current predicted parse, but the noun assignment would cause a new construction of:

Determiner-Modifying Noun-Headnoun-Verb

to be built, resulting in longer times at this position.

The fact that in the noun bias condition items were read more slowly than in the verb bias condition at the POD might be an indication of a late bias effect but there was no interaction of this factor with syntactic ambiguity context. Although not significantly so, the reading times for the ambiguous condition were slower here than for the disambiguated sentences (881 msec vs. 806 msec, respectively) reproducing the same pattern that was seen at the POD in Experiment Ia.

In summary, these data suggest that the current state of the parser can affect, at a very early stage in processing, the selection of one reading of a CA. Lexical bias was no longer a factor in these pronunciation data as it was in Experiment IIa.

Experiment III

Looking at Noun Phrases of Varying Lengths: SPVP with CSD

In the previous Experiments Ia and Ib, there was evidence present in the data for some processing disruption which occurred at the word after the determiner (*bus*) in the case of the DN stimuli (e.g., *these bus stops*) which was not observed in either the DV stimuli or the ambiguous controls. In addition, the number of errors at this point for the DN also supported the occurrence of a processing difficulty. It was postulated that this apparent processing load at the first noun occurred because the parser was expecting the next incoming item to be assigned as the head noun, but received instead a singular noun which did not agree in number with the determiner, and, hence, could not serve as the head noun. In effect, a short garden path had occurred.

Perhaps the parser is acting in a similar manner in the ambiguous case. It might be that the parser is applying the delay strategy here in an attempt to locate the head noun of the noun phrase. It is possible that it is not the categorial ambiguity of the word which causes the parser to delay but the head noun ambiguity.

If the parser assigns the first noun as the head noun, then any subsequent nouns that are encountered supplant the previous noun as the head noun. In fact, the last noun must be the head noun of the noun compound and, therefore, the parser must wait until then to be able to unambiguously assign it as such. Actually, it must wait until the word after the last noun to know that the previous noun was indeed the last. It seems that it would be a reasonable strategy to delay upon receiving a second noun until the end of the noun

phrase is encountered, at which point the noun compound can be constructed and the head noun assigned. The first noun would always be assigned the head noun based on structural bias. That is, nouns are more often used as heads of a noun phrase than as modifiers (Murphy, 1990).

In order to test whether the delay strategy observed in Experiment I was actually the result of encountering a noun compound and not a CA, continuous syntactic decision times in an SPVP task were obtained for noun phrases of different lengths that did not contain any noun/verb CA's.

Experiment IIIa

Three-Constituent Noun Phrases

Method

Subjects

Twenty-seven native English speaking Hunter College students served as subjects in this experiment. None had participated in the previous experiments. Some subjects were offered extra course credit for participating and others volunteered without compensation.

Materials

The materials consisted of 15 noun phrases in sentence frames. Each sentence frame had three variants, each with a different length of the noun phrase. An example frame is shown below:

28a. In our old house the *closet* was much larger

28b. In our old house the *hall closet* was much larger

28c. In our old house the *front hall closet* was much larger

This configuration allows for the direct comparison of syntactic decision times for the word *closet* in the three positions of first (and only) noun, second noun and third noun of the noun phrase. In each comparison, it serves as the head of the noun phrase.

Since there were 15 noun phrases and each had 3 noun constituents, there were a total of 45 nouns in the noun phrase materials. Of these 45 nouns, six had adjective listings in addition to their noun listings in FK. However, only one of the six had a higher frequency listing for the adjective form (*senior*, 26 Adjective:6 Noun).

In summary, the materials consisted of 15 sentence sets, each of which had three versions as above. All versions of each sentence were identical except for the inclusion of zero, one, or two nouns before the head noun.

Periods were omitted in order to avoid cuing subjects that the end of the sentence had been reached. Each subject group saw experimental sentences with only one of the noun compound lengths. This resulted in a design with the random variables of materials or subjects (nested in sentences) and the fixed variables of noun compound length and position of the head noun in the noun phrase. The experimental stimuli were intermixed with 76 fillers with a variety of lengths and structures, 44 of which were ungrammatical at varying positions in the fragment. All experimental and filler items are presented in the Appendix.

Procedure

The procedure was essentially the same as in Experiment Ia. The entire experiment took subjects about 40 minutes. All key presses were timed to the nearest millisecond.

Presses of the "ungrammatical" key in the experimental sentences were coded as errors. In the filler materials, a check of the position of "ungrammatical" responses was used to verify that the subjects were making appropriate grammaticality judgments. Prior to data analysis, decision times greater than two standard deviations above the mean for each subject were replaced with the value for exactly two standard deviations above the mean for that subject.

Predictions

If the parser does not actively search for phrasal heads, but, instead, delays structuring the noun phrase until it is clear that the noun phrase has terminated, there should be an increase in syntactic decision time for (28b and c) compared to the control, (28a), at the word which signals the end of the noun phrase (here the verb *was*). This extra processing after the noun phrase has terminated would reflect assigning the head noun and structuring the rest of the noun phrase.

If, instead, the parser immediately identifies the first noun of the noun phrase as the head noun and then reassigns the head of the noun phrase upon encountering a second noun, syntactic decision times for *closet* in (28b) should be longer than in (28a). This is because the parser will have assigned the first noun as the head in (28b) and will have to backtrack to undo the head noun assignment upon receiving another noun. For (28c), *closet* is also the head noun, but it is the third noun of the noun phrase. It is not clear what the parser will do at the third noun after having erred in assigning the first noun as the head noun of the noun phrase.

Results

Because the only word common to all three versions of the noun phrase was the head noun, this was the only noun position included in the analyses.

Two analyses of variance were first computed to analyze the data. In one, materials, the random effect, were crossed with noun compound length (one, two or three nouns) and word position. Of the 6 positions of the sentence depicted in Figure 8, only four were included in the analysis. They were the determiner of the noun phrase (position 1), the head noun of the noun phrase (position 4), the verb that marked the end of the noun phrase (position 5), and the following word (position 6). In the other analysis, subjects (the random effect) were nested in noun compound length but crossed with the other fixed variables.

The grand mean syntactic decision time was 737 ms. Word position was highly significant in both the materials and subjects analyses: $F_1(3,42) = 13.56$, $p<.0001$ and $F_2(3,72) = 37.91$, $p<.0001$. This main effect for word position indicates that subjects were reading for comprehension. In addition, it was the head noun position (position 4) that was significantly slower than the other three positions. The other significant main effect was for noun compound length, but only in the item analysis: $F_1 (2,28) = 10.46$, $p < .001$.

The interaction of noun compound length by position was also significant: $F_1 (6,84) = 2.22$, $p < .05$ and $F_2 (6,72) = 3.00$, $p < .02$. The is due to the fourth position (head noun) in the two-noun compound length sentence (28b above) exhibiting a significantly longer time than either the one- or three-noun compound length sentences (28a and c, respectively). This is illustrated in Figure 8.

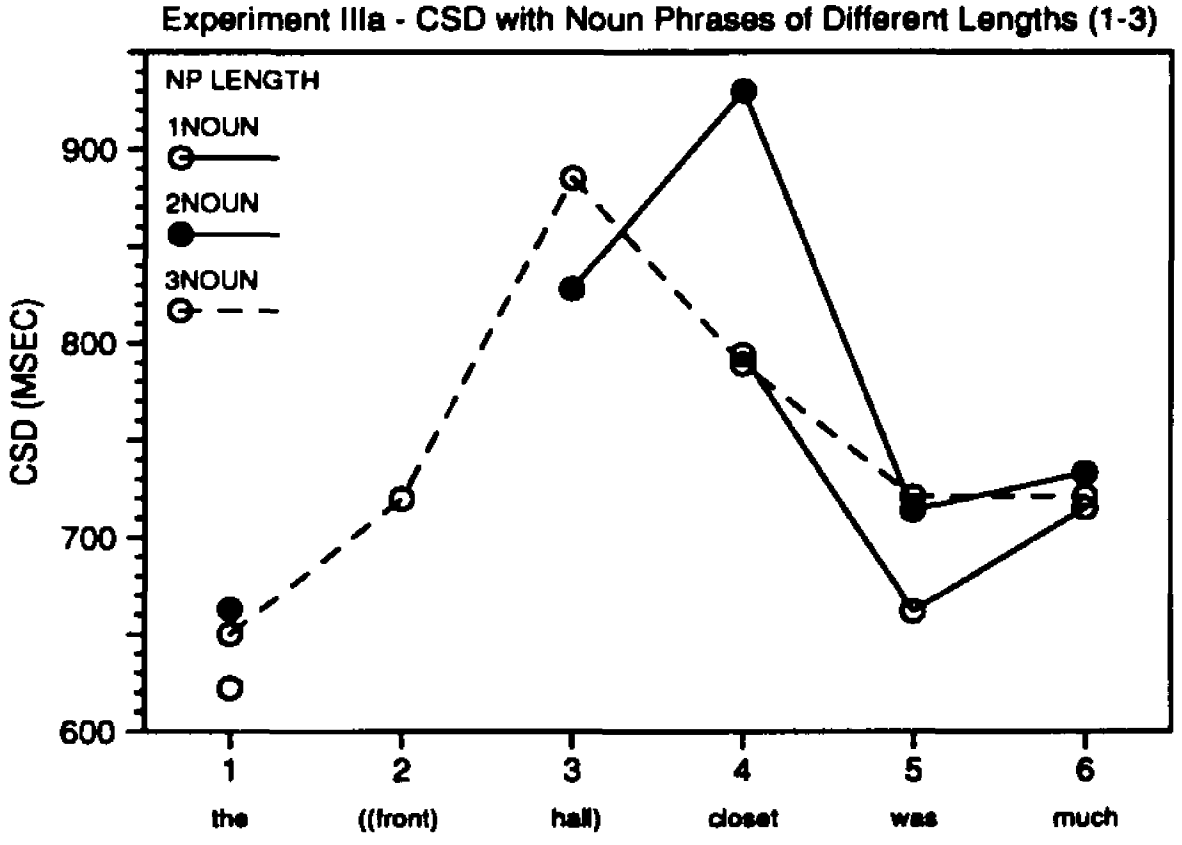

Figure 8. Experiment IIIa - CSD (msec) as a function of noun phrase length and position in sentence.

Discussion

The significant interaction is evidence that the parser had, indeed, assigned the first noun as the head noun in the two-noun compound sentences, and, therefore, had to backtrack upon encountering the second noun. On inspection of the data, a similar pattern can alsobe seen from the first to secondnoun in the 3-noun phrase condition, with the CSD time increasing from *front* to *hall*, suggesting that, here also, the parser had assigned the first noun as the head and then had to reanalyze when the second noun was presented. Note that by the third noun in this condition, the CSD times decrease, suggesting that the parser might no longer be attempting to assign the head noun.

In a recent paper, Frazier (1990) discusses the parsing of noun compounds and concludes that head identification is an incidental decision. She proposes, "Having attached a word under a predicted node, the word is head if nothing more is added under X°. However, if a new word is added under X°, the new item becomes the head according to the righthand head rule... ", and "the new head is identified incidentally as a product of an independently required attachment and at no apparent cost, just like adding an additional word or phrase to the current clause even though the clause could have been a complete well-formed clause without the addition.", (pg. 92). This theorem was principally derived from the data reported in Frazier and Rayner (1987), which we have already discussed as being misinterpreted. That is, the increase at the first noun does appear to occur in their data.

The data presented here seem to contradict this principle as there is certainly evidence of an apparent cost in what appears to be the mistaken assignment of the head noun. Something similar occurred in Experiment Ia and b at the first noun in the DN condition. This looked

suspiciously like the parser was expecting something that could function as the head noun, which the singular noun could not. In particular, these data seem to suggest that, not only is the parser expecting a noun for the obligatory noun node (predicted after receiving the determiner), but that the predicted node is specifically a head noun node, and thus can only be assigned to a potential head noun. This is contrary to what Frazier (1990) hypothesizes. In her model of noun compound parsing, there is no internal structure to the noun compound. This means that all noun nodes are equivalent. Therefore, parsing should not be disrupted if a second noun is encountered because the first noun will not have to be "unassigned". The next noun is just added as another noun node.

These two seemingly disparate versions of how the head noun is assigned can, however, be integrated if we consider a linguistic theory account of parsing noun phrases to explain the parser's preference for a head noun immediately following a determiner, and its abandonment of this preference upon encountering something other than a probable head noun. Consider that the parser is following a reduced version of X-bar theory, in which the intermediate nodes that dominate modifiers are eliminated. In this case, it would predict a determiner and head noun node for the noun phrase. This "short-cut" theory works well, unless an intervening modifier is encountered. At this point, the parser must implement the unabridged X-bar parse construction in order to handle the existence of mediating modifiers. At this point, there is no basis for the parser to make a prediction about whether another modifier or noun is probable as the next item in the phrase.[6]

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[6]I wish to thank Janet Fodor for her linguistic interpretation of this phenomenon.

Therefore, initially the parser expects a head noun following a determiner, and this is reflected in the effects we observed at the second noun (both in the present experiment and in Experiment Ia and b). However, upon encountering a second noun, the parser must switch to a full X-bar implementation. It is in this mode that the parser exhibits Frazier's concept of head assignment, passively accepting each additional member of the noun phrase and incidentally recovering the head noun at the end of the noun phrase, with no cost. This is further substantiated by the results of Experiment IIIb, below.

In summary, it may be concluded that the evidence for delay observed in Experiment I for the ambiguous conditions was, in fact, caused by the CA and not by the occurrence of a potential multiple noun compound.

Another way to test this hypothesis that the parser assigns the first potential noun that it encounters as the head noun is to examine the parsing of noun phrases in which the earlier constituents of the noun phrase are less likely to function as a head noun because their primary (i.e., more frequently used) category is that of an adjective. Bever (1970) presents the segmentation problem of these types of phrases, that is, phrases in which it is not clear where the noun phrase ends. Specifically, he examines the ordering constraints on categorially ambiguous adjective/nouns in noun phrases, and concludes that prenominal adjectives are ordered such that the more nounlike adjectives (e.g., the ones with a higher noun/adjective ratio of frequencies) appear closest to the head noun.

In Experiment IIIa, almost all of the noun constituents of the noun phrase were listed only as nouns in FK. By contrast, in Experiment IIIb, about half of the noun modifiers had higher frequency listings in FK for their adjective use.

Experiment IIIb

Four-Constituent Noun Phrases with Adjective/Noun CA's

Method

Subjects

Twenty-nine native English speaking Hunter College students served as subjects in this experiment. Some subjects were offered extra credit for participating and others volunteered without compensation.

Materials

The materials consisted of 9 noun phrases in sentence frames. Each sentence frame had four variants, each with a different length of the noun phrase. An example sentence set is shown below:

29a. The baby reached for the *cup* on the counter

29b. The baby reached for the *glass cup* on the counter

29c. The baby reached for the *red glass cup* on the counter

29d. The baby reached for the *large red glass cup* on the counter

Again, this configuration allows for the direct comparison of CSD times for the word *cup* in its four positions of first, second, third, and fourth noun of the noun phrase. In each, it serves as the head of the noun phrase and is unambiguously a noun because either there is no other part of speech listing in FK or the syntax constrains it to the noun reading (i.e., although *cup* has a verb usage, the preceding determiner *the* restricts the reading to the noun form).

There were nine noun phrases, each of which incorporated three non-head noun positions, resulting in 27 non-head noun stimuli. Thirteen of these had a higher adjective than noun frequency listing in FK. All of the head nouns were categorially unambiguous nouns in the syntactic context.

In summary, the materials consisted of nine sentence sets, each of which had four version as above. All versions of each sentence were identical except for the inclusion of constituents of the noun compound. This resulted in a design with the random variables of sentences and the fixed variables of noun compound length and position in sentence.

Periods were omitted in order to avoid cuing subjects that the end of the sentence had been reached. Subjects saw sentences with only one type of noun compound. The experimental stimuli were intermixed with 76 fillers with a variety of lengths and structures, 44 of which were ungrammatical at varying positions in the fragment. All experimental and filler items are presented in the Appendix.

Procedure

The procedure is essentially the same as in Experiment 3a above.

Results and Discussion

The discussion of these results will be limited to trends in the data as the design was incomplete (i.e., subjects were not fully crossed with all materials) and there were few stimulus sentences. Two phenomena are noted in the data illustrated in Figure 9. First, the slope from the determiner to the first noun is always positive, as it was in Experiment IIIa. Second, no matter what the length (except in the case of the two-noun length condition),

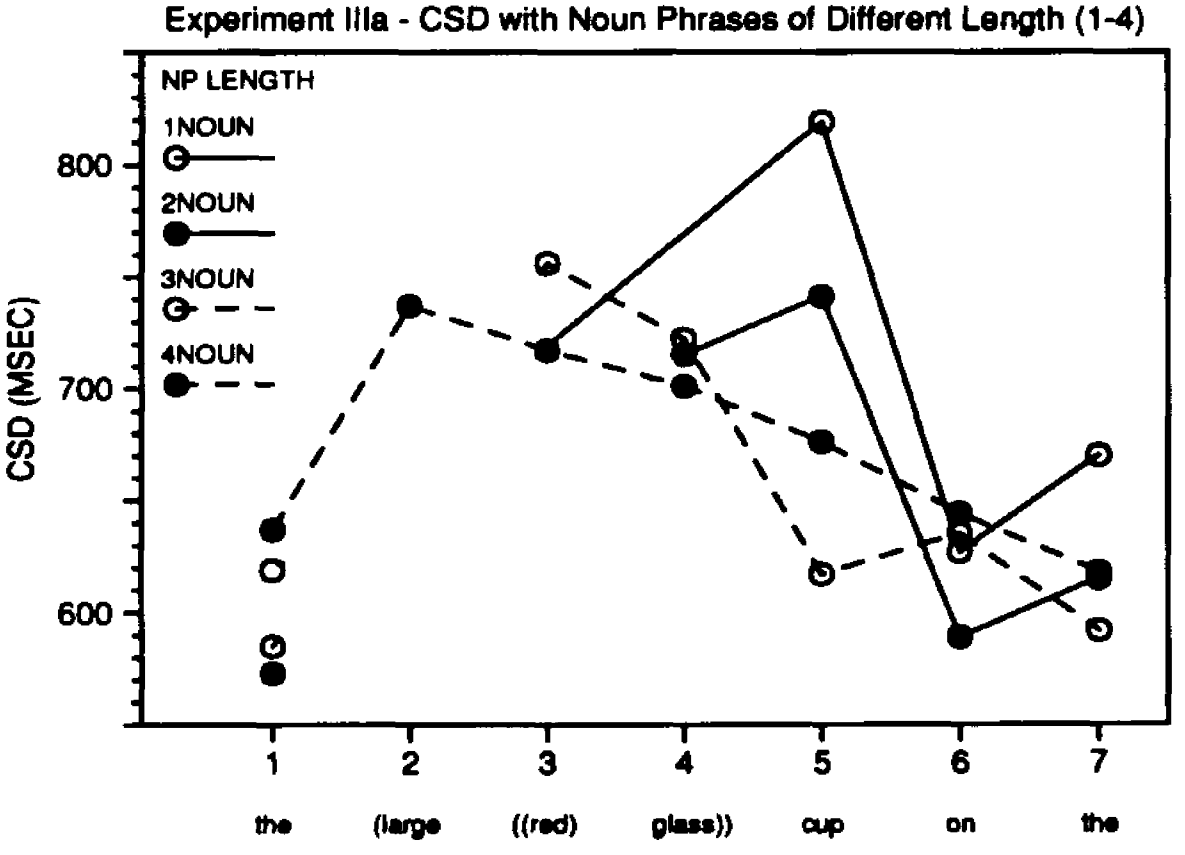

Figure 9. Experiment IIIb - CSD (msec) as a function of noun phrase length and position in sentence.

the slope is negative from the first noun across the noun phrase. The exception of the two-noun length condition can be explained in light of Experiment IIIa. In only one of the nine noun phrases was the noun before the head noun listed as an adjective. This was for the word *elderly* (adjective frequency: 13), and it can be argued that in the 10 or so years since FK was published this word has found increasing use in the language as a noun. This condition acts more like that of the two-noun length phrases in Experiment IIIa, with times increasing from the first to the second noun. However, a rise is not seen from *glass* to *cup* in the three- and four-constituent noun phrases. This suggests that the parser has implemented full X-bar theory upon encountering what it considers to be an adjective in the three- and four-constituent noun phrases, and will, consequently, incidentally recover the head noun at the end of the noun phrase.

Since the earlier noun phrase constituents of the three- and four- noun length phrases are more ambiguous with respect to category (adjective/noun) these words seem not as likely to be considered as head nouns. They are, instead, perhaps perceived and assigned as adjectives immediately, with no adjective/noun CA being detected.

This presents another hypothesis for the parsing of noun phrases that include categorially ambiguous adjective/noun modifiers of the head noun. Because these phrases incorporate CA's, Frazier and Rayner (1987) and Frazier (1990) would predict the use of a delay strategy to parse these phrases. However, the data show that delay is not implemented in this particular case, but rather suggest another hypothesis that the relative frequency of the adjective/noun category affects whether the parser will consider a word as the head noun (dominant noun frequency) or whether it will just be parsed unambiguously as an adjective (dominant adjective

frequency). Because the present Experiment III did not have a complete design, and because the relative frequencies of the constituents of the noun phrases were not experimentally manipulated, this hypothesis suggests a course for future research (discussed below in Future Research).

CHAPTER FIVE: GENERAL DISCUSSION AND CONCLUSIONS

The experiments reported here have suggested that noun/verb categorial ambiguities are parsed using a delay strategy, and that the selection of the appropriate category can be affected at a very early stage of processing, before syntactic processing begins. In addition, lexical bias does not appear to affect the processing of CA's in either ambiguous or unambiguous sentential contexts, however, it does regulate the category selection of a CA in isolation. This suggests that the syntactic processor controls lexical selection in sentence processing. Another finding in these experiments is that the parser seems to apply a "search for phrasal heads" strategy, assigning the head noun of the noun phrase immediately upon encountering an unambiguous noun directly following a determiner.

These data have led to an interpretation of syntactic processing of noun/verb CA's that goes as follows. The parser has an innate preference to structure incoming material as Det-Noun-Verb. In addition, it defaults to Det-Head Noun if the part of speech of the word following the determiner is most probably (has a lexical bias toward) a noun.[7] This strategy is impeded if the noun following the determiner cannot serve as the head of the noun phrase (e.g., the noun *bus* after the determiner *these*). In such cases, the parser must implement a full noun phrase structure, including modifier nodes.

As previously stated, if the word after the determiner can serve as the head noun, the parser assigns it as such and then predicts the following, obligatory verb node. However,

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[7]Another lexical bias factor which may determine whether a word is considered initially to be the head noun is the frequency of usage of that noun as a modifier or head noun. For example, although the unambiguous noun *emergency* may be found as the head of a noun phrase, its more frequent usage is as a modifier to the head noun, as in *emergency room*. This variable has been included in planned future experiments.

if the syntactic context is ambiguous, rendering the next word uncertain with respect to its major category (here the noun/verb CA), the parser delays its assignment until the following word, usually the point of disambiguation. At this position, there are two possibilities. Either the CA has been disambiguated as a verb or as a noun. In the former instance, the previously unassigned word can be delegated to the obligatory verb node, which has already been created. This is the straightforward, expected parse. However, in the latter case, it becomes evident that the initial head noun assignment was incorrect (since the parser has come upon a second noun), and a garden-path phenomenon occurs. Under these circumstances, the parser must reassign the head noun, which involves restructuring the noun phrase (including adding modifier nodes), before it can parse the verb.

The data also support the hypothesis that different senses of CA's share a lexical entry, with both being activated regardless of context. Some of these topics are considered in detail below.

The Syntactic Context Effects

These experiments demonstrate that prior syntactic context can effectively disambiguate CA's. In Experiment Ia, the CSD times for both the noun and verb resolutions in the disambiguated conditions (DN and DV) decreased at the POD compared with their ambiguous controls (AN and AV), which replicates one of the basic findings of Frazier and Rayner (1987). This is mentioned in light of the fact that sometimes, even when the situation seems unambiguous due to available lexical or contextual information, the HSPM may respond in an inappropriate manner (Ferreira and Henderson, 1990; Holmes, 1987; Holmes, Kennedy and Murray, 1987;

see Introduction for discussion).

In addition, because this effect was also observed in the sentential context naming data (Experiment IIb) where pronunciations were determined by the previously presented determiner type (and not by lexical bias as they were in isolation), it can be inferred that this syntactically appropriate selection occurs very early in the processing, perhaps at lexical access, even before full syntactic integration of the CA into the current parse structure.

Further evidence that syntactic context guided access is that there was no evidence that the context effects on naming were inhibitory, i.e., caused by a post-lexical grammaticality check creating output editing effects that would suppress inappropriate pronunciations (Motley, et al., 1981). There was no indication of this in the naming reaction times for appropriate vs. inappropriate pronunciations. In fact, the trend is in the opposite direction. This could be due to the relatively long naming times (in the 700msec range), possibly reflecting more processing than is necessary to perform the naming task. However, Wright and Garrett, 1984, report that their results suggest that some mechanism slows lexical decision times (averaging around 700msec) whenever the target word is syntactically odd with respect to the preceding context. This seems to be the case for the West and Stanovich naming times also, although these times are considerably shorter (approximately 500msec) than the naming times reported here.

Another supporting point that syntactic context had an effect before integration is that mean naming times in isolation (Experiment IIa) were not faster than those in sentences (Experiment IIb), 730msec vs. 695msec, respectively. If anything, naming times in isolation were slower. If significant syntactic processing were occurring in order to select an appropriate

pronunciation in the sentence context experiment, it would seem reasonable to expect some computational cost reflected in the time to pronounce the ambiguous word. Instead, it appears that whatever processing was needed to select the correct pronunciation had already been done.

Note that the naming task does not require syntactic integration of the ambiguous word. However, it does require a choice as there were two possible pronunciations. It might be expected that this choice would have been based on the same factors that controlled naming in isolation, with lexical bias determining the pronunciation and the context not yet having had its effect. This was not the case. Therefore, the effect of the syntactic context was to cause an expectation in the parser so that the appropriate pronunciation could be selected, based on the current state of the parser, without having to wait for the actual syntactic integration of the CA in order to make the appropriate selection. Although different factors determined the pronunciations in isolation and in sentences, no extra processing time was needed by the parser to make the appropriate selection in the sentence condition.

This is not meant to suggest that this syntactic context effect takes the form of activating, for example, all nouns in the lexicon whenever a noun form is required by a constraining syntactic context. This would be untenable and highly inefficient. However, there are other mechanisms by which the syntactic context could affect the access process, perhaps in the way that Rayner and Frazier envision selection as being a by-product of successful integration.

As previously mentioned, one way this early effect of context might be produced is if the syntactic processor has expectations or is searching for a specific part of speech based

on the current parse status. Several naming studies have reported such an effect (Lukatela et al., 1983; West and Stanovich, 1986).

Wright and Garrett (1984) accounted for the syntactic context effects in their lexical decision data by hypothesizing that they "arise from a predictive mechanism that might either be characterized as 'search for phrasal heads' or a top-down prediction of the phrasal categories for which the target words may serve as heads." (pg. 39) Their results were not found only with grammatically correct conditions. They found both relatively slower lexical decision times for noun targets after a final noun (even though this was an acceptable grammatical continuation) and faster lexical decision times to adjective targets when they could act as the phrasal head of the adjective phrase (as compared to adjectives that were not potential heads of phrases but were grammatically acceptable continuations). This led them to conclude that recovering heads of phrases is an important operation of the parser.

Certainly, there was a strong effect on CSD times for the first noun after the DN determiner (*these*) compared to that position for the other types of stimuli. This corroborates the "search for phrasal heads" theory of Wright and Garrett. Since the first noun was singular it could not function as the head noun, causing interference in the parse. More evidence was found for this in Experiment IIIa in which there was a strong suggestion of parsing disruption upon encountering a second noun (but not a third) implying that the first noun had been assigned as the head of the noun phrase but was "unseated" upon confrontation with a second.

Besides the inherent problem that the parser exhibits in encountering a second noun as a result of trying to assign the head noun, Murphy (1990) discusses other aspects of syntactic differences that might contribute to the greater difficulty in parsing noun-noun

constructions. He observes that nouns are more often used as the heads of noun phrases rather than as modifiers, and, therefore there may be more resistance to a noun-noun parse. Or, it may be more difficult to establish a syntactic relation between two nouns as opposed to an adjective-noun pairing.

In addition, Murphy argues that understanding noun-noun (as opposed to adjective-noun) phrases must be a strongly knowledge-dependent process, and his results show that understanding noun-noun phrases is more difficult than understanding adjective-noun phrases. This, he argues, is because adjectives typically represent values along a single dimension (e.g., color) whereas noun meanings are much more complex. To illustrate the complexity of nouns as modifiers, take, for example, the difference between the two meanings of *glass cabinet*, as Murphy has done. It could mean either a cabinet where glasses are stored (stress on the first word) or a cabinet made of glass (stress on the second word). This is contrasted with the noun phrase *green cabinet* which can only be understood in one way (except for the metaphorical reading of a cabinet that is green with envy).

Consider again, for a moment, the results of Experiment Ia. It was found that CSD times at the POD were greater for the AN case than for the AV case. There are two subtly different explanations for these data, and in both, the parser selects the Determiner-Noun-Verb parse. One possibility is that the sequence Determiner-Noun-Verb is structurally preferred and, therefore, is predicted by the parser, but commitment to it is delayed until the CA is resolved. The other explanation is that the parser is intent on assigning the head noun. After it has done so with the first noun, it receives a noun/verb CA. Instead of proceeding with the costly reanalysis of the head noun, it delays until the major category is disambiguated.

The outcomes of these two strategies are virtually identical and both can account for the current data.

A specific strategy of the former explanation that can account for the above mentioned results is that described by Bever (1970) which states "segment together any sequence X..Y, in which the members could be related by primary internal structural relations as actor action object...modifier." In other words, the tendency is to assign N-V-N structure to a string of words if at all possible. Bever remarks that in immediate comprehension tasks using classic garden-path type sentences, subjects could not avoid assigning this structure even after training in which this construction was the incorrect one.

Wright and Garrett also suggest this type of strategy in expecting their noun/noun stimuli (30b) to be nonpreferred compared to the noun/verb (30a) or verb/noun conditions (30c).

30a. The crowd near the church indicates that an important funeral translates

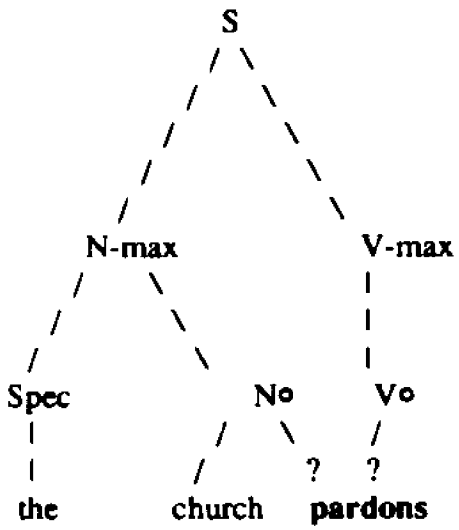
30b. The crowd near the church indicates that an important funeral translation

30c. The towers on the horizon indicate that the barriers isolate translation

Specifically, they say that they would predict a parsing preference for a verb over a noun following a noun.

These are structural preference strategies. But are these the structural preferences predicted by MA? Frazier (1990) suggests not. From her diagram of the phrase *the church pardons*, it appears that attachment of the CA *pardons* as either a sister noun to *church* or as the main verb entails only one node addition. This is depicted in Figure 10. Therefore, MA does not predict a preference for either of these parsing structures. In fact, Frazier states that, in a case where both analyses of an input are equal in terms of number of new postulated

Figure 10. Frazier's (1990) depiction of how the CA *pardons* can be attached into the current parse construction.



nodes, new items are then preferentially incorporated into the current phrase marker (this is an example of an application of another one of the hypothesized rules of the syntactic processor, that of Late Closure). Given a Determiner-Noun sequence and then an ambiguous noun/verb, the two analyses of the ambiguous word would require the same number of new nodes. This would seem to suggest that the preference of the parser might be to take the ambiguous item as a noun and incorporate it into the current (noun) phrase, applying the Late Closure rule. The preferred result would then be Determiner-Noun-Noun, contrary to the predicted preferences as stated by Wright and Garrett, Murphy and Bever, and to the experimental data presented here. Therefore, it is unlikely that Frazier's MA account of structural preference is adequate here.

The preference for Det-N-V over Det-N-N must be due to some other consideration, possibly a preference to close a phrase, although this is contrary to Late Closure. Or, perhaps the propensity to assign the head noun results in the first possible noun being assigned as the head noun. Assuming that it is costly to reassign the head, the next item will be assigned as the verb, if possible. The consequence of this is a N-V-N preference.

Frazier's (1990) concept of how the head of a phrase is assigned rests on the assumption that the process of phrasal head identification is an example of incidental decision making. These types of decisions are really just by-products of other necessary but independent processing decisions and, as such, do not embody any distinct set of rules. She contends that, for example, clause boundary identification is one instance in which no specific strategy is applied, but the clause boundary is revealed as a result of the minimal attachment of each new word into the existing phrase.

In discussing the syntactic identification of the head of a word, Frazier postulates that it is a consequence of attachment by independent attachment principles. There are no specific syntactic processing principles used to assign the head of a word. Instead, if a word is first attached under a predicted node (e.g., noun), that word is the head by default if nothing more is attached by MA under that node. Each new item attached under the same node may become the head by virtue of its being the last word added under the node. In this way, the head is incidentally identified and with no apparent cost.

The experimental basis for this theory of head assignment comes from results on CA's reported by Frazier and Rayner (1987). Specifically, they expected that if the first noun was taken as the head noun, then the noun resolution forms (17a, repeated below) should have taken longer than the verb resolution forms (17b) at the point of disambiguation because of backtracking to reassign the head noun.

17a. I know that the (this) desert trains young people.

17b. I know that the (these) desert trains are tough.

In addition, early assignment of the head noun would predict that the ambiguous and unambiguous verb resolution forms (17b) would not differ since the default preference to take the first noun as the head noun would result in a correct parse in both cases. They reported no evidence that the parser assigned the first noun following the ambiguous determiner *the* as the head noun, although, as stated earlier, this trend does appear to be present in their data.

The data presented in Experiment Ia, here, show that there *was* an overall main effect of resolution, with nouns taking significantly longer than verbs. Also, although the previously

disambiguated noun and verb resolution conditions (DN and DV) did not differ at the POD, the CSD times for the ambiguous noun resolution (AN) stimuli were longer than those for the ambiguous verb resolution (AV). However, the more striking result was the sizeable increase at the first noun after the disambiguating determiner *these* in the DN condition, which Frazier and Rayner claim they did not obtain. However, upon examining their data (Figure 5) the pattern is clearly present. This seems certainly to indicate that the parser is actively searching for the head of the noun phrase, which the first noun (being singular) cannot assume. These results taken together with the results of Experiment III and other research (Mehler, Segui, Pittet and Barriere, 1978; Wright and Garrett, 1984; Murphy, 1990; Pritchett, 1991) are strong support for an active, independent head search mechanism, at least in cases where the context is unambiguous with respect to syntactic category.

Categorial Ambiguities: One Lexical Entry or Two

It is common for dictionaries to list different meanings of a homograph (e.g., the riverside and institution meanings of *bank*) under separate entries, but list different categorial variants of a meaning (e.g., the noun and verb alternatives of *stop*) as subentries under one main entry. The former type of homograph is referred to as a lexical ambiguity. The latter is a syntactic ambiguity or systematic homograph (here, referred to also as systematic CA) and is a special case of polysemy (see below). Could this dictionary type of organization be a viable one for the mental lexicon?

Although, as mentioned before, the naming task does not require syntactic integration of the ambiguous word, the existence of two pronunciations did entail making a selection

by the subject in Experiment II, that is, if the subject were aware that the two alternatives existed. This is very likely, considering that upon questioning after the experiment virtually all subjects reported that they noticed some stimuli had multiple pronunciations. Subjects did occasionally give the inappropriate pronunciation in the full sentential context experiment, suggesting that both the syntactically appropriate and inappropriate forms were at least partially activated at the time of the pronunciation.

If the different alternatives of the systematic CA's had independent lexical entries, it might be expected that the pronunciation times (reflecting lexical access) for the more frequent (dominant) forms would be faster than for the less frequent (subordinate) forms. However, differential naming times were not found in Experiment II. This raises the question of whether, in fact, systematic homographs embody one lexical entry with subentries for each syntactic category (and subcategory?) or whether these types of homographs require a separate lexical listing for each part of speech (and subcategory?).

Ryder and Walker (1982) have reviewed many of the theories that have proposed different structures for the mental lexicon ranging from an early linguistic theory by Katz and Fodor (1963) that describes the lexicon as having multiple meanings (semantic and syntactic) of each homograph all stored in one location in the lexicon to the suggestion by McCawley (1968) that each usage of a form (semantic, syntactic, orthographic, and phonological) necessitates a separate lexical entry. Other intermediate theories are those of Rubenstein, Lewis and Rubenstein (1971), which states that only semantically differentiable homographs constitute a separate lexical listing and a proposal put forth by Lyons (1977) in which only syntactically different forms received separate lexical entries with semantically related forms sharing

an entry. Some of the ensuing research related to systematic homographs is presented below.

In 1970, Rubenstein, Garfield and Millikan established the well-known homograph effect in a lexical decision task which showed that nonsystematic homographs are recognized as words faster than nonhomographs. Their explanation for the basis of this effect was that this type of homograph has more entries in the mental lexicon than nonhomographs.

In a related study, Rubenstein, Lewis and Rubenstein (1971) extended this line of research by investigating the effects on lexical decision of systematic homographs. The hypothesis was that systematic homographs do not have more lexical entries associated with them than nonhomographs (i.e., they have one entry) and, therefore, lexical decision times to systematic homographs would not differ from nonhomographs. This was what the results bore out. In addition, the relative frequency of the meanings of systematic homographs did not have a consistent effect on lexical decision times, which they took as further evidence that systematic homographs are represented as one entry in the lexicon.

Ryder and Walker (1982) also found similar effects for systematic homographs, or what they term "syntactically ambivalent words." In a synonymy judgment task, subjects took no longer for unambiguous controls than for systematic homographs, but only in the case where the matched synonym was for the more dominant usage of the systematic homograph (e.g., *cart-wagon*). Judgments were significantly longer when the synonym was related to the less frequent syntactic category than for unambiguous controls (e.g., *cart-carry*). They concluded from these results that only the dominant usage of a systematic homograph is initially activated.

A similar problem can be demonstrated with the Forster and Bednall (1976) experiment,

which also tested different types of homographs in a syntactic function task where the word is presented with a previously syntactically disambiguating word (e.g., *to house* vs. *the house*). The subject is to decide whether the stimulus is grammatical. They also differentiated the stimuli with respect to the dominant and subordinate meanings of the homograph.

Forster and Bednall found their results for the systematic homographs to be puzzling. Syntactic decisions did take significantly longer for the subordinate reading, but most of this difference (70 out of the 87 msec)[8] was accounted for by the interruption time involved in bypassing the dominant form. The remaining 17msec additional time to access the subordinate form was considered to suggest that this was searching within the lexical entry. In other words, the bulk of the time was in accessing the main entry within which the dominant form was listed first and then the subordinate forms.

The perplexing finding was that access time for the subordinate meaning was correlated with neither the frequency of the dominant or subordinate form nor the access time for the dominant form. They, therefore, concluded that access is independent for the two forms. Again, the task requirements might be the cause of conflicting frequency effects.

A suggestion by Rohrman and Gore (1973) might be applicable here. They examined systematic homographs using both a recall and a sentence creation task. Either the ambiguous form or an unambiguous (noun or verb) alternative of the ambiguity was presented in a

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[8]The 70msec estimate for the interruption time (time taken to pass a listed entry) comes from calculations on other conditions in the experiment. In particular, the time to say "No" for an exhaustive search in the case of a nonword (e.g. *to soarmer, the flink*) was approximately 70msec shorter than the time to say "No" in an ungrammatical word pair (e.g. *the beg, to opera*) in which the word is accessed but must be passed by as ungrammatical, with the search continuing to the end.

list either for recall or for use in a sentence (e.g., *light, lamp, illuminate*). They found that systematic ambiguities were recalled better and used faster than the unambiguous controls. Rohrman and Gore's results caused them to conclude that if systematic homographs are stored in a single entry then the entry does not have to be scanned serially (e.g., by frequency) but could be accessed independently. This might be an explanation for the contradictory results of other studies that access of the subordinate sense did not seem to be correlated with that of the dominant one.

More experimental data that suggest that systematic homographs share a lexical entry comes from the Carpenter and Daneman (1981) study that shows a strong effect of relative frequency on pronunciation times for unsystematic homographs. Indeed, relative frequency accounted for much more of the trend in the data than did context. Even in a strong biasing context for the subordinate form, subjects rarely gave the subordinate pronunciation when the relative frequency of the dominant form was very high. In contrast, the data from Experiment IIb here show a syntactic context effect but no bias effect. This discrepancy could be because, while unsystematic homographs have separate listings with independent activation thresholds (which depends on frequency of occurrence), systematic homographs share an entry with some representative frequency affecting its access.

Further support that systematic homographs comprise only one entry comes from the results of Experiment IIa in which naming times for equiprobable homographs (the two forms had equal bias) were not longer than for either noun or verb bias ones. This is contrary to the results of Rayner and Duffy (1986) and Rayner and Frazier (1989) which showed longer processing times in eye movement studies for equiprobable stimuli. However, their

homograph stimuli were not systematic, therefore, a frequency effect would be expected based on the fact that the different meanings of the homograph would comprise separate lexical entries.

Although some of these other experimental findings include some discrepancies, taken together with the present data, there is more reason to suspect that polysemous words constitute only one inclusive lexical entry.

A final consideration of polysemy and the structure of the lexicon follows from a discussion of such in Anderson and Ortony (1975). They consider cases of polysemy to include not only systematic CA but also semantic sense (see also Frazier and Rayner, 1990). For example, consider the different meanings of the word *eat* in (31).

31a. The senator ate the steak.

31b. The baby ate the steak.

31c. The dog ate the steak.

The distinct meanings evoked in each of these sentences are attributed to the different agents. Also, contrast the senses of *eat* in the following phrases: *eat steak, eat soup, eat an apple*. Here it is the actions of the mouth and the utensil that differ.

Following Wittgenstein (1963), who argued that it is frequently not possible to give the necessary and sufficient conditions for the use of a word, Anderson and Ortony believe that it would be unreasonable for each potential sense of a word to have a separate listing. For instance, one can classify items alphabetically, by color, by size, etc. It is unlikely, however, that everything is permanently classified this way. Rather, semantic relationships are dynamic and are generated during the comprehension of a sentence with heavy dependence

on world knowledge and sentential context. It becomes obvious that the idea of having a separate listing for each nuance of a polysemous word is not a realistic solution for the organization of the mental lexicon and that there must be substantial reliance on both pragmatic and contextual information in order to interpret the full meaning of the usage of a word.

Conclusions based on the major findings of this work can be summarized in the following list.

1) **Noun/Verb categorial ambiguities are parsed by means of a Delay strategy.** The results from Experiment I offer further support for Frazier and Rayner's (1987) evidence for a Delay parsing strategy in the case of noun/verb categorially ambiguous words. The disambiguated conditions showed greater syntactic decision times in the ambiguous region than the syntactically ambiguous versions and the reverse was found at the POD. This is the pattern that is predicted by the Delay strategy for these stimuli. However, the results of Experiment IIIb suggest that the Delay strategy is not implemented in general for all types of CA, specifically not for Adjective/Noun CA's.

2) **The parser appears to predict or project a syntactically preferred parse.** Evidence for differential parsing at the POD for the two ambiguous conditions in CSD was proposed to be due to the fact that the syntactic processor had projected a syntactically preferred parse structure of Det-Noun-Verb (obligatory, e.g., verb, nodes are predicted) which was in agreement with the verb resolution of the AV sentences at the POD, thus resulting in a relatively easy resolution of the ambiguity there. In contrast, the AN sentences showed evidence of relative slowed processing

at the POD caused by the disparity between the resolution of the CA as a noun and the predicted construction by the parser of D-N-V.

3) **The parser employs a strategy that actively searches for phrasal heads.** The data promote the "search for phrasal heads" account of Wright and Garrett. This was seen in the results of Experiment Ia at position 2 (the first noun) for the DN materials in which the determiner did not agree in number with the following noun. It was argued that this would only occur if the parser was, in fact, expecting (predicting) an item that could function as the head noun at this position. Additional evidence for this was seen in the results of Experiment IIIa in which the parser demonstrated difficulty upon encountering a second noun after a first noun, that was a potential head noun, had already been parsed. This effect was not observed in Experiment IIIb in which the items before the head noun were less likely candidates for the head noun position.

4) **The noun/verb CA can be effectively disambiguated by previous disambiguating syntactic context.** The fact that this context has an effect immediately, at the categorially ambiguous word, is inferred from fast syntactic decision times at the POD for the syntactically disambiguated sentences relative to the syntactically ambiguous sentences. The naming data from Experiment IIb that show more appropriate pronunciations of the CA for the DN and DV conditions corroborate this.

5) **The locus of the syntactic context effect is placed at a very early stage of sentence processing,** arguably during lexical processing. This was concluded both from the result that it was syntactic context, and not lexical bias, that was able to

effect the appropriate pronunciation of the CA for the disambiguated versions and the assumption that the naming task yields times representative of lexical processing and is not contaminated by post-lexical events.

This is not equivalent to saying that syntactic context restricts lexical access to the appropriate form, only that syntactic context can be used to select among the candidates in the initial stages of processing. This distinction depends on whether lexical access and selection are thought of as components of one mechanism or as two separate operations. Put another way, it is not whether context can have an effect on lexical processing but when. Recall that even the Modular view of the HSPM allows the eventual application of different kinds of context and pragmatic knowledge, but these are not assumed to affect lexical processing, only some later stage. The view expounded here supports the one-mechanism theory of lexical access (as in Tabossi, 1988), and, as such, permits extralexical material and knowledge to affect lexical processing. One possible mechanism by which this can be accomplished is enabling these external sources of information to alter the excitation levels of lexical entries during lexical access, which, in effect, determine selection (see below).[9]

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[9]Note that it is only because the naming task necessitates a decision that we can observe the syntactic context effect in these naming data. Otherwise, recall that in Experiment Ia, evidence for delay was shown (indicating that both senses were activated). This implies that, if a decision does not need to be made, the parser opts to wait, which means, in effect, that multiple readings will remain active (within some absolute time constraints) until the POD, if possible. This could explain why syntactic context effects on lexical processing are obtained here but not in cross-modal priming studies, notably Prather and Swinney (1977), Tanenhaus et al. (1979), Seidenberg et al. (1982), where a categorial selection is not required to complete the task.

6) **The state of the parser (due to internal syntactic preference) can aid in the selection component of lexical processing**. This was inferred from the naming preferences for the ambiguous materials in Experiment IIb for which the pronunciation of the verb form was given as often as for the DV condition. It was argued that the verb form was more often selected by subjects because the current state of the parser preferred a verb at the CA, which was considered an internal preference strategy of the syntactic processor. This is distinct from the influence of syntactic context on pronunciation (5 above) which stems from an external source of information, that of the sentence.

7) **Lexical bias is represented in the mental lexicon for the different forms of CA's.** In Experiment IIa, naming in isolation followed from the bias of the item. That is, CA's with a noun lexical bias were pronounced more often as nouns and CA's with a verb lexical bias were pronounced more often as verbs. Equibiased items were equally likely to be pronounced as nouns or verbs. This suggests that when a decision is forced (as it is in the naming task) the selection is based on lexical biases when no other information is available on which to base a decision (note that when these same stimuli were presented in a sentence, Experiment IIb, the decision was based on syntactic context or preference and not on lexical bias, which suggests that the syntactic processor has priority when it is in operation as in the case of sentence processing, as opposed to pronunciation in isolation, and can override the preference of the lexical processor).

8) **The various meanings of polysemous homographs (e.g., CA's) are stored as subentries together in a single main lexical entry.** This follows from the failure to find any naming time differences for the dominant vs. subordinate pronunciations in Experiment II. This reduces the question of exhaustive vs. selective access to a moot point, assuming that it is not possible for the system to access only one of the subentries without activating the other members of the main entry. However, frequency of each form within the entry is represented (see 7 above).

CHAPTER SIX: PROPOSED FUTURE RESEARCH

The constituents of the noun compound in the stimuli in Experiment IIIa were chosen to be categorially unambiguous nouns. There are, of course, others types of words which are categorially ambiguous, e.g., some being used more often as adjectives and some more often as nouns. Are noun phrases containing these types of categorially ambiguous words processed differently from those that have been heretofore examined in Experiment III? (This was suggested in Experiment IIIb, but the necessary controlled materials were not included).

Frazier (1990) has proposed the principle of Primacy of Syntactic Category Resolution (based on the CA work with Rayner, 1987) which states that "the syntactic processor operates on X°'s disambiguated with respect to major category features." In other words, the processor delays at a CA until its category assignment can be ascertained. It is important here to ask whether the adjective/noun CA has any functional relevance to the parser.[10] It is clear that this ambiguity would be important to the parser if it were, in fact, searching for the head noun (a point with which Frazier disagrees) because an adjective cannot function as a head noun.

Therefore, based on Frazier's Primacy principle, it would be important for the parser to resolve the adjective/noun ambiguity regardless of whether it is, indeed, actively seeking out the head noun. If the category assignment of the ambiguous adjective/noun CA must

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[10]The relevance to the parser of the adjective/noun distinction refers to whether the parse tree for an Adjective-Noun construction is different from that of a Noun-Noun. If the two structures are functionally identical, then the CA distinction should be inconsequential to the parser.

be resolved before further processing can occur, then there should be evidence for a delay strategy in the form of an increase in reaction time at the POD. This point might be at the first unambiguous noun or not until the parser has encountered an element that cannot precede the head noun in the noun phrase (e.g., a preposition or a verb).

In addition, if the parser takes the first unambiguous noun to be the head, then any subsequent nouns will cause the parser to backtrack since the head noun assignment will have to be revised. Suppose the parser dose not delay. What role might lexical bias play in its decision? If a CA whose dominant usage is as an adjective is encountered, it might be more likely to be parsed as an adjective than a CA with noun dominant usage, which the parser might be more tempted to take as the head noun.

In order to examine parsing of adjective/noun categorially ambiguities, sentences incorporating these types of words in noun compounds could be generated as below in (32):

32a. The *squeaky* door...

32b. The *red* door/is...

32c. The *front* door/is...

32d. The *car* door/is...

(32a) uses an unambiguous adjective, that is, this word only has an adjective frequency listing in FK. In (32b), the CA *red* is used which has a dominant adjective meaning (FK 169/11 for adjective and noun listings, respectively). The CA *front* in (32c) has a dominant noun meaning (77/153 for adjective and noun listings) and in (32d) there is an unambiguous noun. All these versions except (a) can be presented either with a following noun (e.g., *door*) or verb (e.g., *is*). In this way, the word can act as its own control and can be compared

for a both a noun and verb resolution.

In a CSD task using these stimuli, the following might be predicted at the third word, the POD. In the noun resolution condition (*door*), times for (32d) should be greater than for the verb resolution version (*is*). This follows from the results of Experiment III reported here. That is, the parser should take the first noun *car* as the head noun and then have to unassign it upon encountering *door*, which is another noun. The time for (32a) should also be faster than for (32d) in the noun resolution condition because in (32a) the parser will have parsed the unambiguous adjective correctly.

In addition, if the italicized words in (32a and d) are controlled for length and frequency, they can be compared. In this way, it is possible that a test of MA could be applied. MA predicts that (32d) should be faster than (32a) because the noun node is obligatory and, thus, predicted, whereas, the adjective node is optional and, therefore, would have to be added upon encountering an adjective. Another perspective is that the parser is operating in reduced X-bar mode if it receives a noun, but has to implement full X-bar theory upon encountering an adjective. This should also result in an increase at the adjective compared to the noun.

The more interesting case is for the CA conditions. A longer CSD time is predicted for (32b) for the noun than for the adjective resolution condition. The converse is true for (32c). This is contrary to the prediction for a delay strategy that would expect an increase for both CA's at either resolution.

Another way to test this is with a second set of stimuli as in (33) below.

33a. These *noisy* ...

33b. These *red* ...

33c. These *front* ...

33d. These *car* ...

These stimuli would have to be compared to each other and, therefore, would have to be controlled for surface (combined) frequency and length (obviously, the examples are not). Here, (33a and b) should pattern together as should (33c and d). The first two should be handled as adjectives after the determiner and yield results similar to those of Experiment IIIb, with no increase in processing load. However, the second two should cause disruption as did the DN condition in Experiment Ia and b, because the parser is expected to try to take the next potential noun as the head noun, which is not a grammatical continuation.

In considering all the preference factors that could influence how a reader might parse an ambiguous word, one further variable that was not controlled in these stimuli needs to be mentioned. It is possible that the frequency of usage of the first noun as a noun modifier could affect its assignment. For example, the noun *emergency* is more often used as a noun modifier than a head noun (e.g., *emergency room*). Phrases such as these might not induce the parser to assign the first noun as the head, since it most frequently does not serve that function. The main hypothesis to test, then, is that in adjective/noun CA's, the assignment of the CA is determined by the relative frequency of the alternate forms and is not delayed until some later POD, which was found for noun/verb CA's in the results of Experiment IIIb. This allows the claim that all CA's are parsed using a delay strategy to be further tested. It is expected that adjective/noun CA's are not parsed using a delay strategy.

Appendix

Experimental Materials

Experiment Ia

EVEN BIAS:

Every hour a radio broadcasts the world news report
Every hour the radio broadcasts the world news report
Every hour these radio broadcasts are repeated in full
Every hour the radio broadcasts are repeated in full

For our parties the restaurant supplies the appetizers
For our parties all restaurant supplies are rented
For our parties a restaurant supplies the appetizers
For our parties the restaurant supplies are rented

In an emergency the town reserves the right to impose regulations
In an emergency the town reserves can be rationed
In an emergency a town reserves the right to impose regulations
In an emergency those town reserves can be rationed

In first grade these school reports are more promising for children
In first grade this school reports more children are graduating
In first grade the school reports are more promising for children
In first grade the school reports more children are graduating

In general this government protests the use of chemicals in warfare
In general the government protests the use of chemicals in war
In general all government protests are widely publicized
In general the government protests are widely publicized

It is better if the airline schedules don't conflict
It is better if an airline schedules most flights early
It is better if the airline schedules most flights early
It is better if these airline schedules don't conflict

Next quarter the company estimates are going to be
Next quarter this company estimates a rise in profits
Next quarter the company estimates a rise in profits
Next quarter those company estimates are going to be

NOUN BIAS:

Before the battle the warrior faces the sun to pray
Before the battle all warrior faces are painted black
Before the battle the warrior faces are painted black
Before the battle a warrior faces the sun to pray

By state law the bank exchanges are monitored
By state law the bank exchanges foreign money
By state law this bank exchanges foreign money
By state law those bank exchanges are monitored

In this magazine the automobile rates very highly
In this magazine these automobile rates are higher
In this magazine this automobile rates very highly
In this magazine the automobile rates are higher

In town the neighborhood patrols dangerous areas
In town these neighborhood patrols are very dangerous
In town the neighborhood patrols are very dangerous
In town this neighborhood patrols dangerous areas

Often these club groups are politically effective
Often the club groups are politically effective
Often a club groups together similar people
Often the club groups together similar people

This month the bill amounts are more than I can afford
This month this bill amounts to more than I can afford
This month the bill amounts to more than I can afford
This month these bill amounts are more than I can afford

For tax purposes the town records are available
For tax purposes these town records are available
For tax purposes the town records all property sales
For tax purposes this town records all property sales

VERB BIAS:

After midnight these truck stops are more frequent
After midnight the truck stops are more frequent
After midnight a truck stops at every station

After midnight the truck stops at every station

On Wednesday a bus guides the group through town
On Wednesday the bus guides the group through town
On Wednesday those bus guides were more friendly to us
On Wednesday the bus guides were more friendly to us

On white paper a pencil marks very easily
On white paper the pencil marks very easily
On white paper these pencil marks show better
On white paper the pencil marks show better

The judge said this criminal looks guilty and dangerous
The judge said the criminal looks guilty and dangerous
The judge said the criminal looks were menacing to the jury
The judge said those criminal looks were menacing to the jury

They reported that this city permits buses to park here
They reported that these city permits are difficult to obtain
They reported that the city permits buses to park here
They reported that the city permits are difficult to obtain

When it is hot the dog bites more viciously
When it is hot these dog bites are more severe
When it is hot a dog bites more viciously
When it is hot the dog bites are more severe

The mayor believes that the homeless cause more crime
The mayor believes that these homeless cause more crime
The mayor believes that this homeless cause is a worthy
The mayor believes that the homeless cause is a worthy

Experiment 1b

EVEN BIAS:

MY MOTHER'S RECIPE SAYS THAT A BEEF ROASTS AT A HIGH TEMPERATURE.
MY MOTHER'S RECIPE SAYS THAT THE BEEF ROASTS AT A HIGH TEMPERATURE.
MY MOTHER'S RECIPE SAYS THAT THE BEEF ROASTS CAN BE DEFROSTED.

MY MOTHER'S RECIPE SAYS THAT THESE BEEF ROASTS CAN BE DEFROSTED.

IN THIS COUNTRY ALL GOVERNMENT PROTESTS ARE WIDELY PUBLICIZED.
IN THIS COUNTRY THE GOVERNMENT PROTESTS ARE WIDELY PUBLICIZED.
IN THIS COUNTRY THE GOVERNMENT PROTESTS THE USE OF CHEMICALS IN WAR.
IN THIS COUNTRY THIS GOVERNMENT PROTESTS THE USE OF CHEMICALS IN WAR.

IN MY CAR THE WINDOW SHIELDS AGAINST THE SUNLIGHT.
IN MY CAR THE WINDOW SHIELDS ARE GOOD FOR SUNLIGHT.
IN MY CAR THESE WINDOW SHIELDS ARE GOOD FOR SUNLIGHT.
IN MY CAR THIS WINDOW SHIELDS AGAINST SUNLIGHT.

FOR OUR PARTIES A RESTAURANT SUPPLIES THE APPETIZERS.
FOR OUR PARTIES ALL RESTAURANT SUPPLIES ARE RENTED.
FOR OUR PARTIES THE RESTAURANT SUPPLIES ARE RENTED.
FOR OUR PARTIES THE RESTAURANT SUPPLIES THE APPETIZERS.

IT IS BETTER IF AN AIRLINE SCHEDULES MOST FLIGHTS EARLY.
IT IS BETTER IF THE AIRLINE SCHEDULES DON'T CONFLICT.
IT IS BETTER IF THE AIRLINE SCHEDULES MOST FLIGHTS EARLY.
IT IS BETTER IF THESE AIRLINE SCHEDULES DON'T CONFLICT.

IN GENERAL A CARPENTER MEASURES MORE ACCURATELY THAN I DO.
IN GENERAL THE CARPENTER MEASURES ARE MORE ACCURATE THAN MINE.
IN GENERAL THE CARPENTER MEASURES MORE ACCURATELY THAN I DO.
IN GENERAL THESE CARPENTER MEASURES ARE MORE ACCURATE THAN MINE.

EVERY HOUR A RADIO BROADCASTS THE WORLD NEWS REPORT.
EVERY HOUR ALL RADIO BROADCASTS ARE REPEATED.
EVERY HOUR THE RADIO BROADCASTS ARE REPEATED IN FULL.
EVERY HOUR THE RADIO BROADCASTS THE WORLD NEWS REPORT.

IN AN EMERGENCY A TOWN RESERVES THE RIGHT TO IMPOSE REGULATIONS.
IN AN EMERGENCY THE TOWN RESERVES CAN BE RATIONED.
IN AN EMERGENCY THE TOWN RESERVES THE RIGHT TO IMPOSE REGULATIONS.
IN AN EMERGENCY THOSE TOWN RESERVES CAN BE RATIONED.

FOR THIS QUARTER THE COMPANY ESTIMATES ARE LOWER THAN BEFORE.
FOR THIS QUARTER THE COMPANY ESTIMATES THAT THEY ARE AHEAD.
FOR THIS QUARTER THIS COMPANY ESTIMATES THAT THEY ARE AHEAD.
FOR THIS QUARTER THOSE COMPANY ESTIMATES ARE LOWER THAN BEFORE.

IN THE FIRST GRADE THE SCHOOL REPORTS ARE MORE PROMISING FOR CHILDREN.
IN THE FIRST GRADE THE SCHOOL REPORTS MORE CHILDREN ARE GRADUATING.
IN THE FIRST GRADE THESE SCHOOL REPORTS ARE MORE PROMISING FOR CHILDREN. IN THE FIRST GRADE THIS SCHOOL REPORTS MORE CHILDREN ARE GRADUATING.

NOUN BIAS:

IN THE BACK OFFICE A MANAGER PHONES THE FRONT DESK.
IN THE BACK OFFICE THE MANAGER PHONES ARE NOT WORKING.
IN THE BACK OFFICE THE MANAGER PHONES THE FRONT DESK.
IN THE BACK OFFICE THOSE MANAGER PHONES ARE NOT WORKING.

BEFORE THE BATTLE THE WARRIOR FACES THE SUN TO PRAY.
BEFORE THE BATTLE A WARRIOR FACES THE SUN TO PRAY.
BEFORE THE BATTLE ALL WARRIOR FACES ARE PAINTED BLACK.
BEFORE THE BATTLE THE WARRIOR FACES ARE PAINTED BLACK.

ON THE OTHER SIDE OF TOWN THE NEIGHBORHOOD PATROLS ARE VERY DANGEROUS.
ON THE OTHER SIDE OF TOWN THE NEIGHBORHOOD PATROLS DANGEROUS AREAS.
ON THE OTHER SIDE OF TOWN THESE NEIGHBORHOOD PATROLS ARE VERY DANGEROUS.
ON THE OTHER SIDE OF TOWN THIS NEIGHBORHOOD PATROLS DANGEROUS AREAS.

THIS MONTH THE BILL AMOUNTS ARE MORE THAN I CAN AFFORD.
THIS MONTH THE BILL AMOUNTS TO MORE THAN I CAN AFFORD.
THIS MONTH THESE BILL AMOUNTS ARE MORE THAN I CAN AFFORD.
THIS MONTH THIS BILL AMOUNTS TO MORE THAN I CAN AFFORD.

BY STATE LAW THE BANK EXCHANGES ARE MONITORED.
BY STATE LAW THE BANK EXCHANGES FOREIGN MONEY.
BY STATE LAW THIS BANK EXCHANGES FOREIGN MONEY.
BY STATE LAW THOSE BANK EXCHANGES ARE MONITORED.

THE FISHERMAN EXPLAINED THAT THE BAIT HOOKS ARE IMPORTANT.
THE FISHERMAN EXPLAINED THAT THE BAIT HOOKS THE FISH.
THE FISHERMAN EXPLAINED THAT THESE BAIT HOOKS ARE IMPORTANT.
THE FISHERMAN EXPLAINED THAT THIS BAIT HOOKS THE FISH.

IT IS OFTEN THE CASE THAT A CLUB GROUPS TOGETHER SIMILAR PEOPLE.
IT IS OFTEN THE CASE THAT THE CLUB GROUPS ARE POLITICALLY EFFECTIVE.
IT IS OFTEN THE CASE THAT THE CLUB GROUPS TOGETHER SIMILAR PEOPLE.
IT IS OFTEN THE CASE THAT THESE CLUB GROUPS ARE POLITICALLY EFFECTIVE.

FOR TAX PURPOSES A TOWN RECORDS ALL TRANSACTIONS.
FOR TAX PURPOSES ALL TOWN RECORDS ARE AVAILABLE.
FOR TAX PURPOSES THE TOWN RECORDS ALL TRANSACTIONS.
FOR TAX PURPOSES THE TOWN RECORDS ARE AVAILABLE.

IT IS GOOD THAT A CHURCH BENEFITS AS A NONPROFIT ORGANIZATION.
IT IS GOOD THAT THE CHURCH BENEFITS AS A NONPROFIT ORGANIZATION.
IT IS GOOD THAT THE CHURCH BENEFITS RAISE A LOT OF MONEY.
IT IS GOOD THAT THESE CHURCH BENEFITS RAISE A LOT OF MONEY.

IN SPRING WEATHER A TREE FLOWERS IN A FEW WEEKS.
IN SPRING WEATHER THE TREE FLOWERS ARE IN FULL BLOSSOM.
IN SPRING WEATHER THE TREE FLOWERS IN A FEW WEEKS.
IN SPRING WEATHER THESE TREE FLOWERS ARE IN FULL BLOOM.

VERB BIAS:

THE JUDGE SAID THE CRIMINAL LOOKS GUILTY AND DANGEROUS.
THE JUDGE SAID THE CRIMINAL LOOKS WERE MENACING TO THE JURY.
THE JUDGE SAID THIS CRIMINAL LOOKS GUILTY AND DANGEROUS.
THE JUDGE SAID THOSE CRIMINAL LOOKS WERE MENACING TO THE JURY.

ALONG THIS HIGHWAY ALL ROAD BENDS ARE SLIPPERY WHEN RAINING.
ALONG THIS HIGHWAY THE ROAD BENDS ARE SLIPPERY WHEN RAINING.
ALONG THIS HIGHWAY THE ROAD BENDS SHARPLY EVERY FEW FEET.
ALONG THIS HIGHWAY THIS ROAD BENDS SHARPLY EVERY FEW FEET.

WITH THE COMMERCIAL BRAND THE POT HANDLES ARE BRASS PLATED.
WITH THE COMMERCIAL BRAND THE POT HANDLES TWO QUARTS.
WITH THE COMMERCIAL BRAND THESE POT HANDLES ARE BRASS PLATED.
WITH THE COMMERCIAL BRAND THIS POT HANDLES TWO QUARTS.

ON WEDNESDAY A BUS GUIDES THE GROUP THROUGH TOWN.
ON WEDNESDAY THE BUS GUIDES THE GROUP THROUGH TOWN.
ON WEDNESDAY THE BUS GUIDES WERE MORE FRIENDLY TO US.
ON WEDNESDAY THOSE BUS GUIDES WERE MORE FRIENDLY TO US.

FROM EACH PRISON A CONVICT ESCAPES WITHOUT BEING CAUGHT.
FROM EACH PRISON THE CONVICT ESCAPES WITHOUT BEING CAUGHT.
FROM EACH PRISON THOSE CONVICT ESCAPES HAVE INCREASED DRAMATICALLY.
FROM EACH PRISON THE CONVICT ESCAPES HAVE INCREASED DRAMATICALLY.

AFTER MIDNIGHT A TRUCK STOPS AT EVERY STATION.
AFTER MIDNIGHT THE TRUCK STOPS ARE MORE FREQUENT.
AFTER MIDNIGHT THE TRUCK STOPS AT EVERY STATION.
AFTER MIDNIGHT THESE TRUCK STOPS ARE MORE FREQUENT.

AT THE RACE TRACK A BOOKIE BETS MORE SUCCESSFULLY.
AT THE RACE TRACK THE BOOKIE BETS ARE MORE SUCCESSFUL.
AT THE RACE TRACK THE BOOKIE BETS MORE SUCCESSFULLY.
AT THE RACE TRACK THOSE BOOKIE BETS ARE MORE SUCCESSFUL.

THE MAYOR FEELS THAT THE HOMELESS CAUSE IS WORTH FIGHTING FOR.
THE MAYOR FEELS THAT THE HOMELESS CAUSE MORE CRIME.
THE MAYOR FEELS THAT THESE HOMELESS CAUSE MORE CRIME.
THE MAYOR FEELS THAT THIS HOMELESS CAUSE IS WORTH FIGHTING FOR.

WHEN IT IS HOT A DOG BITES MORE VICIOUSLY.
WHEN IT IS HOT THE DOG BITES ARE MORE SEVERE.
WHEN IT IS HOT THE DOG BITES MORE VICIOUSLY.
WHEN IT IS HOT THESE DOG BITES ARE MORE SEVERE.

THE OFFICE REPORTED THAT THE CITY PERMITS ARE DIFFICULT TO OBTAIN.
THE OFFICE REPORTED THAT THE CITY PERMITS BUSES TO PARK HERE.
THE OFFICE REPORTED THAT THESE CITY PERMITS ARE DIFFICULT TO OBTAIN.

THE OFFICE REPORTED THAT THIS CITY PERMITS BUSES TO PARK HERE.

Experiment Ic

WORD COMPLETION:

bends
faces
measures
rates
protests
marks
hopes
passes
fights
stops
bets
exchanges
broadcasts
supplies
records
aims
estimates
escapes
reserves
shields
flowers
phones
reports
schedules
benefits
groups
roasts
patrols
guides
hooks
looks
cause
permits

amounts
bites
handles

PHRASE COMPLETION:

the road bends
the warrior faces
the carpenter measures
the automobile rates
the government protests
the pencil marks
the parish hopes
the movie passes
the court fights
the bus stops
the bookie bets
the bank exchanges
the radio broadcasts
the restaurant supplies
the town records
the team aims
the company estimates
the convict escapes
the town reserves
the window shields
the tree flowers
the manager phones
the school reports
the airline schedules
the church benefits
the club groups
the beef roasts
the neighborhood patrols
the bus guides
the bait hooks
the criminal looks
the homeless cause
the city permits
the bill amounts
the dog bites
the pot handles

Experiment IIa

EVEN BIAS:

desert
imprint
insult
misuse
perfume
permit
pervert
predicate
protest
relay
torment

NOUN BIAS:

abuse
addict
address
combat
conflict
contest
delegate
excuse
export
graduate
import
progress
refund

VERB BIAS:

advocate
alternate
associate

attribute
compress
conduct
construct
consult
convert
convict
decrease
escort
estimate
incline
increase
insert
postulate
reject
repeat
separate
suspect
use

Experiment IIb - # indicates word presented for naming

NOUN BIAS:

We all know that the government #abuses are
We all know that these government #abuses are tolerated
We all know that this government #abuses its citizens

The study found that the drug #addicts many
The study found that this drug #addicts many
The study found that those drug #addicts recover

An article stated that this company #addresses issues
An article stated that the company #addresses are
An article stated that these company #addresses are wrong

In class the professor announced that the schedule #conflicts with
In class the professor announced that a schedule #conflicts with his
In class the professor announced that these schedule #conflicts can

In the afternoon those committee #delegates are meeting

In the afternoon a committee #delegates the agenda
In the afternoon the committee #delegates are

When the supply is good this store #exports more
When the supply is good the store #exports more
When the supply is good these store #exports become

On next Wednesday this student #graduates with honors
On next Wednesday those student #graduates will have a party
On next Wednesday the student #graduates with honors

In an upcoming book these plot #intrigues are fiction
In an upcoming book this plot #intrigues the reader
In an upcoming book the plot #intrigues are fiction

At the downtown location this store #refunds any purchase
At the downtown location those store #refunds expire tomorrow
At the downtown location the store #refunds expire tomorrow

VERB BIAS:

The chairman said a company #associates with its benefactors
The chairman said the company #associates went out of business
The chairman said those company #associates went out of business

At the clinic the nurse #consults were available
At the clinic those nurse #consults were available
At the clinic a nurse #consults every hour

In special classes these church #converts attend
In special classes the church #converts believers
In special classes this church #converts believers

In the next quarter those company #estimates will be lower
In the next quarter this company #estimates higher profits
In the next quarter the company #estimates will be lower

The management said the wage #increases the company debt
The management said these wage #increases are unfair
The management said this wage #increases the company debt

On the assembly line a machine #rejects bad parts

On the assembly line these machine #rejects get discarded
On the assembly line the machine #rejects get discarded

Once a year the city #permits public debate
Once a year this city #permits public debate
Once a year these city #permits are renewed

For the upcoming election the club #advocates fair
For the upcoming election this club #advocates fair
For the upcoming election these club #advocates are running

In the fall the course #alternates are offered
In the fall a course #alternates between
In the fall those course #alternates are offered

Experiment IIIa

In our old house the closet was much larger
In our old house the hall closet was much larger
In our old house the front hall closet was much larger

I couldn't get in because the opener was broken
I couldn't get in because the door opener was broken
I couldn't get in because the garage door opener was broken

The children made a playhouse out of the carton that was
The children made a playhouse out of the refrigerator carton that was
The children made a playhouse out of the cardboard refrigerator carton that was

He was scared of the turtle at the zoo
He was scared of the sea turtle at the zoo
He was scared of the giant sea turtle at the zoo

There is a discount on
There is a citizen discount on
There is a senior citizen discount on

He hated it when the truck came
He hated it when the garbage truck came
He hated it when the city garbage truck came

I wanted the frame for the painting
I wanted the picture frame for the painting
I wanted the gold picture frame for the painting

At each corner was a guard for the children
At each corner was a crossing guard for the children
At each corner was a school crossing guard for the children

In the winter a comforter is best for cold nights
In the winter a down comforter is best for cold nights
In the winter a goose down comforter is best for cold nights

He said that the oil was the best to cook with
He said that the olive oil was the best to cook with
He said that the virgin olive oil was the best to cook with

She spoke about the lawyer in a nasty tone
She spoke about the court lawyer in a nasty tone
She spoke about the divorce court lawyer in a nasty tone

I thought the curtain was more expensive
I thought the bedroom curtain was more expensive
I thought the lace bedroom curtain was more expensive

The news reported that the body was striking
The news reported that the student body was striking
The news reported that the college student body was striking

He had an album to show us
He had a picture album to show us
He had a vacation picture album to show us

You will find it in the drawer by the
You will find it in the utensil drawer by the
You will find it in the kitchen utensil drawer by the

Experiment IIIb

He preferred the cushion on
He preferred the seat cushion on
He preferred the rubber seat cushion on

He preferred the foam rubber seat cushion on

The apartment had floors in all
The apartment had wood floors in all
The apartment had parquet wood floors in all
The apartment had oak parquet wood floors in all

He was proud of the collection that his
He was proud of the stamp collection that his
He was proud of the old stamp collection that his
He was proud of the rare old stamp collection that his

The baby reached for the cup on the counter
The baby reached for the glass cup on the counter
The baby reached for the red glass cup on the counter
The baby reached for the large red glass cup on the counter

The victim was a woman who
The victim was an elderly woman who
The victim was a fat elderly woman who
The victim was a short fat elderly woman who

They replaced the old one with a rug that covered
They replaced the old one with an area rug that covered
They replaced the old one with a wool area rug that covered
They replaced the old one with a pure wool area rug that covered

I got the space that
I got the parking space that
I got the available parking space that
I got the last available parking space that

He liked the player that
He liked the disc player that
He liked the compact disc player that
He liked the portable compact disc player that

He took his bicycle on the tour
He took his racing bicycle on the tour
He took his speed racing bicycle on the tour
He took his ten speed racing bicycle on the tour

FILLERS

Experiment Ia

The reporter believed that the editor was amusing
The mother expected that the newspaper would arrive at any moment
The delivery man noticed the youngster was outside
The businessman forgot the taxi would be waiting at the airport
The rescuers discovered the survivor when they made a last attempt
The pirate demanded the contraband when he boarded the injured vessel
The private investigator studied the clergyman when he arrived in the
The detective spotted the jewels when he threw back the curtain
The witness remembered that the woman stayed by the pool most of the
The warden doubted that the story had been completely true
The tour guide found the anthropologists were still in the room
The committee reported the books were new to the school
The youngster imagined her daddy when she needed to feel safe
The gray-haired gentleman recalled the dog but could not find another
The judge refused the lawyer but was dissatisfied with his effect
The inspector passed the girls when the factory doors opened
The physician discussed the patient when she learned he had abused drugs
The young poet heard that the singer was incredibly beautiful
The cashier that the customer considered honest became was
The chef cooked the roast on the include
The swimmers trained hard for the race
Some people believe that their best the
The diligent lawyer found the policy to be much never
The oldfashioned barber that the hairdresser brought the liking
The resourceful teacher found that the children all and
The company that beside
The newscaster that reported the information to about
The best guitarist playing acoustic jazz is undoubtedly were
The man that when
Although the rewards were merely was
The scouts that why
The frustrated musician moved the piano from the basement to the sing
The dogs that is
Two men rode quickly store
The skilled jeweler made the bracelet with the asked
By state law the bank exchanges are monitored
The careful waiter that carried the salad was extremely lettuce
All of run
The bitter cold forces people lose

The city worker met the district representative for seems
The school that end
The manager escorted the visitor think
Finishing the race was all some why
Little time has been door
Each sheep had been died
The sheriff arrested the tell
Whoever finds the course too table
The singer reported the song for with
The only answer floor
It around
They sold the painting smile
Weary of the long drive them
The coach insisted that the new when
Within of
Before we tomorrow
The helpful caretaker carried the statue from the garden to the under
Many trees were injured pipe
He believed someone was spying on
Those clues that the people decided very errors
The detective questioned our neighbor after the
Their slanderous comments annoy could
The impending nuclear teach
The hero leaped to the without
Too few cups us
During a competition this horse show its ability
The cow that the butcher warned us about was the know
The clamps that who
Near the arena was standing might
The before
The mechanic that however
The fearful soldiers guarded the office near the translate
The respectful nuns that watched the baby at laughed
An enjoyable his
If all goes too while
The priest that if
The proud dancer that showed the director his studio with under

Experiment Ib

THE MAN WITH THE TELESCOPE SPOTTED THE PLANE.
THE PATRON'S DRINK WAS SERVED BY THE BARTENDER.
PATIENTS ARE HELPED BY THE MEDICINE IN DRUGSTORES.
THE COMMERCIAL PRESENTED MISLEADING CLAIMS ABOUT THE PRODUCT.
FRED DISCOVERED THE COMBINATION TO JOHN'S LOCK.
THE BOY WAS GIVEN A TREAT BY TIM'S GRANDPARENTS.
CHRISTOPHER WAS BUMPED BY TOM'S TRUCK.
FRAN WAS HUGGED BY MARY'S UNCLE.
THE NEW OFFICE WAS RENTED BY THE COMPANY'S MANAGER.
THE BALLERINA'S TOESHOE WAS BROKEN BY THE UNDERSTUDY.
THE REPAIRMEN FIXED THE SMITH'S HOUSE.
THE CHIEF OF THE FOREST RANGERS PLANTED TREES.
SAM'S LITTLE DAUGHTER KICKED THE POSTMAN.
THE DRIVER OF THE TRUCK UNLOADED THE CEMENT.
THE BOY'S MOTHER WAS ARRESTED BY THE POLICEMAN.
THE COACH'S BEST PLAYERS WERE SUSPENDED BY THE DEAN.
THE OWNER OF THE RESTAURANT PREPARED THE FOOD.
NELLY'S BOSS WAS CRITICIZED BY THE WOMAN.
THE BOY'S TUITION WAS PAID BY THE GUARDIAN.
THE BOY'S BASEBALL HIT THE FATHER.
THE CLIENTS' LAWSUIT WAS DEFENDED BY THE LAWYERS.
THE STUDENT'S EXAM WAS MISPLACED BY THE INSTRUCTOR.
THE WOMAN'S DRUG WAS ADMINISTERED BY THE NURSE.
THE WOMAN'S JEWELRY DELIGHTED THE QUEEN.

Experiment IIa

supply
reserve
report
exchange
patrol
amount
divorce
utensil
collection
available
because
refrigerator
garage
emergency
before
relate

couch
prepare
display
accent
compliment
contact
impress
review
control
shelf

Experiment IIb - # indicates word presented for naming: $ indicates follow-up question

The patient sat in bed but got up to
The cats are wearing party clothes for the
The woman #tried
Parking the car is so inconvenient #when it is dark
Those beer bottles are piling up in the #doorway outside
The new tenant had a lease $
The soup that was boiled
The depressed man awoke cheerfully seven hours #later
The pirate demanded that the contraband be thrown out $
The police that they told about the riots voted to
The private investigator noted that the #clergyman remained in the hotel lobby
The pencil sharpener is full
The detective revealed
The musicians #that played here are gone
The small group
The young poet heard the #singer
The director met in the morning
The boat that was in the water
Please change the baby
My new #computer
The assassin had #killed more than once
The people warned about the
The dancers who were found dead were
The nosy reporter called at night $
The oil poured on the clothes
The gray-haired gentleman recalled that the desk was #brown $
The elderly lady crossed the street $
The judge requested that the lawyer remain in the courtroom

When the show closes she will collect unemployment $
The inspector #saw
The #material was wet
It's not the heat
My battery was stolen again last
The letters mailed at the post office were never delivered $
The final exam
Those are the same pants you wore
The woman forgot her umbrella the #day it rained $
The #holiday is coming
Next month will be the
Her work is improving and #maybe she will get a raise
The tickets were #distributed
The rules created by the new government were #strictly
Please give me a minute
When the young boy saw
The only bad thing that happened yesterday was minor
She had been aware that he liked her
Clean up your room $
She purchased new #shoes
If you would be more comfortable then sit down
The chemistry exam was easier to study for $

Experiment III

The reporter believed that the editor was unusual
The mother expected that the attorney would charge exorbitant fees
The delivery man noticed that the idea was not difficult to understand
The businessman forgot that the driver was dirty
The rescuers discovered the weather was calmer on the north slope
The pirate demanded the captive pay for the damages
The private investigator noticed that the clergyman was spattered with
The detective revealed that the government was sponsoring aid for the
The witness remembered the woman was injured in the commotion
The warden doubted that the prisoner had been completely honest
The tour guide found that the anthropologists needed some assistance
The committee reported the sociology was seriously behind the times
The youngster imagined the thought had turned into a magic dragon
The gray-haired gentleman recalled that the dog was perfect
The judge requested the lawyer remain outside the courtroom
The inspector saw that the noise had caused permanent structural damage

The physician judged that the patient was getting stronger
The young poet heard the singer was incredibly beautiful
The cashier that the customer considered honest became was
The chef cooked the roast on the include
The swimmers trained hard for the race
Some people believe that their best the
The diligent lawyer found the policy to be much never
The oldfashioned barber that the hairdresser brought the liking
The resourceful teacher found that the children all and
The company that beside
The newscaster that reported the information to about
The best guitarist playing acoustic jazz is undoubtedly were
The man that when
Although the rewards were merely was
The scouts that why
The frustrated musician moved the piano from the basement to the sing
The dogs that is
Two men rode quickly store
The skilled jeweler made the bracelet with the asked
By state law the bank exchanges are monitored
The careful waiter that carried the salad was extremely lettuce
All of run
The bitter cold forces people lose
The city worker met the district representative for seems
The school that end
The manager escorted the visitor think
Finishing the race was all some why
Little time has been door
Each sheep had been died
The sheriff arrested the tell
Whoever finds the course too table
The singer reported the song for with
The only answer floor
It around
They sold the painting smile
Weary of the long drive them
The coach insisted that the new when
Within of
Before we tomorrow
The helpful caretaker carried the statue from the garden to the under
Many trees were injured pipe
He believed someone was spying on
Those clues that the people decided very errors
The detective questioned our neighbor after the

Their slanderous comments annoy could
The impending nuclear teach
The hero leaped to the without
Too few cups us
During a competition this horse show its ability
The cow that the butcher warned us about was the know
The clamps that who
Near the arena was standing might
The before
The mechanic that however
The fearful soldiers guarded the office near the translate
The respectful nuns that watched the baby at laughed
An enjoyable his
If all goes too while
The priest that if
The proud dancer that showed the director his studio with under

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