Abstract

Recent work on the nature of syntactic ambiguity has focused on the properties of lexical items that may be relevant to resolving such ambiguities. A variety of lexical properties have been proposed as having significant influence on syntactic ambiguity resolution. Ranging from referential properties (Ni, Crain, & Shankweiler 1996), in the context of the Referential Model of language processing, to subcategorization properties and frequencies associated with morphological variants of particular verbs (MacDonald, Pearlmutter, & Seidenburg 1994), in the context of a constraint-based approach to processing. The present eye-movement study provides empirical support for the claim of MacDonald et al. that relative frequencies of simple past tense versus past participle forms of regularly inflected verbs influence parsing decisions made when such verbs are encountered in sentences exhibiting a reduced-relative clause/main-verb ambiguity. However, this paper challenges the MacDonald et al. theoretical claim that the existence of such effects poses a serious challenge to modular models of language processing as a class, and provides an account of such effects within the Referential Model of language processing. In this account the effect of frequency bias on parsing decisions is argued to reduce to an effect of frequency on lexical access latency.

Garden Path Sentences and Morphological Frequency Biases

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1 Introduction

There are two main schools of thought with respect to the information available to the human parsing mechanism. Highly interactive models (Tanenhaus & Trueswell, 1995; Carpenter & Just, 1983; Taraban & McClelland, 1990) put few restrictions on the interaction of various types of information in the course of sentence processing. On the other hand, the weakly interactive Referential Model of Crain and Steedman (1985), and the strictly serial Garden-Path Model of Frazier (1979) place heavy restrictions on the interplay of different types of information during parsing. Recent trends in the development of both sorts of models have focused on the influences of lexical properties and lexically encoded information on parsing decisions.

1.1 Lexical Properties and (Temporary) Syntactic Ambiguity

Ni (1991), using a self-paced word-by-word reading technique, and Ni, Crain, and Shankweiler (1996), using the technique of recording eye-movements during reading, provide evidence that the presence of the focus operator *only* in the subject NP can serve to eliminate the typical garden-path effect seen in sentences in which the subject is modified by a reduced relative clause (RRC) headed by a morphologically ambiguous verb. Subjects encountering (1a) typically (incorrectly) analyze the verb *loaned* as the simple past tense main verb of the matrix clause as evidenced by elevated reading times at the actual inflected verb of the matrix clause, *were*, compared to a control sentence with an unambiguous verb, (1c).

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(1) a. The businessmen loaned money at low interest were told to save the receipts.
b. Only businessmen loaned money at low interest were told to save the receipts.
c. The vans stolen from the parking lot were found in a back alley.
d. Only vans stolen from the parking lot were found in a back alley.

Substituting *only* for *the* eliminates this garden-path effect. Reading times in the disambiguating portion (beginning with *were*) of sentences like (1a) are significantly elevated when compared with control (1c), while reading times for the same region of (1b) are not significantly different from its control, (1d). Ni et al. provide an explanation of these facts that appeals to the focal properties of *only* in the context of the Referential Model of parsing (Crain & Steedman, 1985; Ni, 1991).

Researchers working within the context of interactive models of parsing have focused on the relevance to parsing of other sorts of lexical properties. Trueswell and Tanenhaus (1994) explore the goodness of thematic fit between subject and ambiguous verb, exemplified in the fragments in (2), as an influence on parsing decisions.

(2) a. The fossil examined ...
b. The archeologist examined ...

The verbs in either fragment can be interpreted as simple past or as passive participle, but because *fossil* makes a poor agent the verb *examined* is more likely to be interpreted as a passive participle heading a reduced relative clause than as a past tense main verb. The converse is true in (2b) because *archeologist* makes a good agent for the verb, supporting the general bias toward main verb interpretation. Trueswell and Tanenhaus provide evidence from eye-movement experiments that thematic properties do influence parsing decisions.

MacDonald, Pearlmutter, and Seidenberg (1994) suggest that biases associated with argument structure ambiguities are relevant to parsing decisions. They observe that many verbs are associated with more than a single argument structure. Main verb *race*, for example, has the transitive and intransitive uses shown in (3).

(3) a. The man raced the horse past the barn yesterday.
b. The horse raced past the barn yesterday.
c. The horse raced past the barn fell.

On their proposal the strong garden path effect in (3c) is due, in part, to the fact that *race* is used more often as an intransitive than as a transitive verb (Connine, Ferreira, Jones, Clifton, & Frazier, 1984). In (3c) *race* has a (logical) object, *the horse*; Instantiation of the low frequency option contributes to a strong garden path effect. In a sentence where the frequency of the transitive subcategorization frame is relatively high, the MacDonald et al. hypothesis predicts that the strength of the garden path effect would be reduced. MacDonald (1994, experiment 3) offers data from self-paced reading experiments that supports this prediction.

The constraint satisfaction model argued for in MacDonald et al. (1994) has it that lexical representations provide a variety of constraints on syntactic parsing decisions. In addition to the biases associated with argument structure ambiguities, they contend that the relative frequency with which the *-ed* form of a verb is used as a past-tense versus past-participle will influence the parsing decision made when the verb is encountered in an ambiguous context as in (1), (2), or (3). Evidence that they provide for this claim comes from the post hoc analysis of some dozen studies of reading times in sentences with the reduced-relative/main-verb ambiguity seen in (1)-(3).

Specifically, MacDonald et al. (1994) claim that the relative frequencies of simple-past versus past-participle uses of the verbs in these studies mediate the strength of the garden path effects found, and whether or not "contextual" manipulations were able to exert an influence on parsing preferences. Using counts from Francis and Kučera (1982), they determined that mean past-participle use of verbs in the twelve experiments ranged from a low of 44.4% to a high of 75.8%. They contend that verb sets in studies which found no influence of context on garden path effects, a finding generally taken as support for a modular language processor in the sense of Fodor (1983), tend to be biased toward the simple past tense. On the other hand, verb sets in studies which showed an influence of context on garden path effects tend to be biased toward the past-participle use.

On the MacDonald et al. account, the relative frequencies of simple past versus past participle use should have an influence on parsing decisions made in sentences like (1)-(3). The goal of the eye-movement experiment described in section 2 is to test this prediction by manipulating the relative frequencies with which the *-ed* forms of sets of regular verbs occur in simple-past and past-participle contexts and examine the effect that this has on parsing decisions in reduced-relative/main-verb ambiguities as evidenced by reading times downstream from the ambiguous verb, where subsequent information forces a particular disambiguation. The most straightforward prediction to be derived from the MacDonald et al. hypothesis is that sentences in which the ambiguous verb heads a reduced relative will show less of a garden path effect if the ambiguous verb is biased toward past-past participle use than if it is biased toward past-tense use. On the other hand, in sentences where the ambiguous verb is a past-tense main verb, readers will experience some difficulty if the verb is biased toward past-participle use as opposed to past-tense use. In effect we predict an interaction of the morphological (frequency) bias of a verb and the structural position that it actually occupies. Although the results of this experiment provide some support for the MacDonald et al. prediction, I will challenge their claim that this result poses a serious challenge for modular models of language processing in general.

If effects of syntactic ambiguity and of lexical ambiguity are handled through the same mechanism as MacDonald et al. (1994) claim, then we expect that effects of lexical ambiguity (seen in homophonic-homographs like *bank* and *perch*) on reading time measures will carry over to the ambiguous verbs in sentences like those in (1)-(3). In

order to see why this might be so we review work that has shown an influence of lexical ambiguity on patterns of eye movements.

1.2 Lexical Ambiguity and Eye Movements

Rayner and Duffy (1986) demonstrate that lexical ambiguity and word sense frequency influence fixation time. They examined fixation times on ambiguous words in neutral contexts, contexts that did not favor either meaning of the word. They found that ambiguous words that have roughly equal frequencies for their different meanings (equibiased), like *punch* in (4a), are fixated longer than unambiguous controls (in parentheses). This contrasted with ambiguous words in which one sense is more frequent (non-equibias), *perch* in (4b). In this case the ambiguous words were not fixated longer than unambiguous controls.

(4) a. We thought the punch (cider) was delicious.
b. He saw the perch (trout) had avoided the hook again.

Duffy, Morris, and Rayner (1988) examined fixation times on ambiguous words in biasing contexts. They manipulated the context preceding the ambiguous word such that the context was either neutral or supported the subordinate meaning of the ambiguous word.[2] In neutral contexts their results replicated those of Rayner and Duffy (1986). They extended those results with the finding that when ambiguous words are preceded by a biasing context supporting their subordinate meanings the pattern is reversed. Fixation times on equibiased ambiguous words are not different from those of non ambiguous controls, but fixation times on non equibiased ambiguous words are elevated compared to controls. Duffy et al. argue for a model of lexical access in which all senses of ambiguous words are exhaustively (nominally) accessed in order of frequency, but which allows context to interact with frequency to reorder the sequence in which words are accessed. They term this the Reordered Access Model.

Rayner and Frazier (1989) explicitly compared fixation times on equibiased versus non-equibiased ambiguous words in both neutral and biasing contexts. They found that in neutral contexts the equibiased ambiguous words were read more slowly than the non-equibiased ones. But, when the context preceding the ambiguity biases the subordinate sense of non-equibiased ambiguous words the pattern is reversed. These results are entirely consistent with the earlier findings of Rayner and Duffy (1986), and Duffy, Morris, and Rayner (1988). However, Rayner and Frazier propose a model in which context does not affect speed of lexical access, but does affect the speed with which a word sense is integrated into the context once it has been accessed. They term this the Integration Model. It shares with the earlier model that, in the general case, senses of ambiguous words are accessed in order of frequency. One difference between

2 Duffy et al. also looked at effects of biasing contexts following ambiguous words (where context preceding the word was neutral). Not surprisingly such contexts do not effect fixation times on the ambiguous words.

this and the Re-ordered Access Model is that in the Integration Model word senses are not always exhaustively accessed. Once one sense of a word is successfully integrated into the context, access to subordinate senses is pre-empted.

The empirical generalization that can be drawn from these studies is that when a local bias, arising from a lexical ambiguity, runs counter to a global bias, deriving from context, readers experience difficulty in processing, as evidenced by elevated fixation times at the ambiguous word. Pacht and Rayner (1993) call this the *subordinate bias effect*. This effect is arguably relevant to the MacDonald et al. (1994) claim.

Returning to the main-verb/reduced-relative ambiguity, most researchers agree that verbs in contexts like those preceding the ambiguous verbs in (1)-(3) are typically interpreted as past tense main verbs because a sequence like *The NOUN VERBed ...* inherently favors the simple past tense use of a verb, and so disfavors the past participle use. This is true, for example, for Frazier and Clifton (1996), Ni, Crain, and Shankweiler (1996), and Trueswell and Tanenhaus (1994), although they propose different accounts of the bias. If syntactic ambiguity is reducible to lexical ambiguity as MacDonald et al. (1994) claim then we reasonably predict that the ambiguous verbs that are the locus of the reduced relative clause/main verb ambiguity will behave as do lexically ambiguous words in the studies conducted by Rayner and colleagues. The prediction is that verbs with a bias towards past participle use placed in a context which inherently favors the past tense use, like *The NOUN VERB...*, will have elevated fixation times relative to verbs biased toward past tense use.

2 The Experiment

The purpose of this eye movement experiment is two-fold. The primary goal is to determine whether the relative frequency of simple-past versus past-participle use of verbs has a significant influence on the resolution of reduced-relative/main-verb ambiguities like those seen in (1)-(3), as MacDonald et al. (1994) claim. This will be determined by examining fixation times downstream of the ambiguous verb itself, at a region of the sentence containing information that disambiguates the verb toward either the past tense or past participle use. The garden path effect due to the main-verb/reduced-relative ambiguity typically manifests itself as elevated fixation times in this disambiguating region of reduced-relative sentences with respect to fixation times in the same region of main-verb type sentences. An interaction of sentence type and morphological (frequency) bias will provide support for the MacDonald et al. claim. More specifically, this hypothesis predicts that ambiguous verbs with *-ed* forms biased toward past-participle use (relative to simple past tense) will exhibit a weaker garden path effect than will verbs with *-ed* forms biased toward simple past tense use.

Second, the effect of frequency bias at the ambiguous verb itself is examined to determine if there is a subordinate bias effect similar to that seen in lexical ambiguities deriving from unrelated homophones of the *bank, perch* sort. In the present experiment the presence of this effect should manifest itself as elevated fixation times on verbs

biased toward past-participle use as contrasted with those biased toward simple past use since the bias of the former runs counter to the contextual bias of the frame *The NOUN VERB-ed....*

2.1 Method

2.1.1 Participants

Twenty-four undergraduate students were paid six dollars each to participate in this experiment. All were native speakers of English and reported vision that was normal or corrected to normal with soft contact lenses. Participants were naive to the purpose of the experiment.

2.1.2 Materials

Twenty-four test sentences were constructed for the experiment. These were embedded in a matrix of seventy-four filler items. The factor "frequency bias" was manipulated in the following way. Twelve sets of three verbs each were constructed using the following criteria. First, every verb is regularly inflected and so participates in the simple-past/past-participle ambiguity in its *-ed* inflected form. Second, the *-ed* form of one verb in each set occurs more frequently in the simple past tense than as a past participle (the *past* condition). A second verb is not strongly biased in either direction (the *equi* condition). The third verb is used more frequently as a past-participle than in the past tense (the *ppart* condition).[3]

The frequency of simple-past, and past-participle use for each verb was determined using Francis and Kučera (1982).[4] The mean frequency for each group of verbs is shown in (5). The percentage of past-participle *-ed* forms, relative to the total number of *-ed* inflected occurrences, is shown in the first column. Notice that the manipulation of relative past participle frequency is of sufficient magnitude to encompass both ends of the range of past participle use for the 12 studies examined by MacDonald et al. (1994) (these ranged from a low of 44.4% to a high of 75.8%). If frequency bias is a confounding factor in the studies as MacDonald et al. claim, then the manipulation of the bias in these materials should be sufficient to produce an effect. Ideally, as the degree of bias toward past participle usage increases, we would expect reading times to increase monotonically at the disambiguating regions of sentences in which the ambiguous verb is in fact a main verb, and to decrease monotonically at the same region of sentences in which the verb heads a reduced relative clause.

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3 The complete set of test materials can be found in the appendix.

4 The morphological categories used by Francis and Kučera are relatively coarse. They conflate, for example, perfect and passive *-ed* forms in a single category, which they label VBN. This is a potential confound in that the two participles differ in thematic and argument structure. A verb's thematic/argument structure is not perfectly correlated with its status as a past-participle. In this experiment, I use the VBN counts as a measure, while acknowledging that this makes it impossible to separate out effects of thematic/argument structure.

(5) Table shows mean frequencies of *-ed* forms as past tense (*past*),as past participle (*ppart*), and frequency of the stem in all inflectional forms combined (*stem*) for each bias set and for all three bias sets combined, as well as the percentage of *-ed* inflected uses that are past participle (*% ppart*) (Francis and Kučera, 1982).

	Mean Frequencies (sd)						**%**
Bias Set	**Past**		**PPart.**		**Stem**		**PPart**
past	34.2	(36.8)	12.1	(12.0)	99.9	(120.4)	26.2
equi	19.3	(18.2)	25.6	(26.6)	105.8	(101.9)	57.0
ppart	8.8	(5.6)	39.4	(25.8)	116.8	(128.7)	81.7
all verbs	20.8	(25.5)	25.7	(24.6)	107.5	(114.3)	55.3

An attempt was made to hold the mean stem frequency of the verbs in each of the three conditions constant. Stem frequency refers to the summed frequencies of all of the inflectional variants of a verb.[5] The average stem frequency for each condition is shown in the last column of (5). While the match is not perfect, the difference that remains between any two conditions is non-significant by t-test.

Twenty-four sentence frames were constructed, two for each set of verbs. Each frame is designed so that each verb from the relevant set can appear in it felicitously, both as main verb and as the head of a reduced relative clause modifying the subject noun. (6) contains an example verb set with the associated Francis and Kučera counts, and (7) shows these verbs embedded in a sentence frame.

(6) Sample verb set with associated frequencies.

Verb	**past count**	**ppart count**	**bias set**
rush	20	7	past
crowd	8	24	ppart
press	12	16	equi

The presence versus absence of *but* in the frame forces either the past tense main verb interpretation of the ambiguous verb, as in (7a-c), or the past participle reduced relative

5 The Francis and Kučera (1982) counts are the number of occurrences in a corpus of roughly one million words. Their label for total stem frequency is LEMMA.

clause interpretation, as in (7d-f). I will refer to this factor as "continuation type," and the two levels as main-verb (MV) and reduced-relative (RR) respectively.

(7) a. The felons rushed into the cellblock but couldn't see the warden.
b. The felons crowded into the cellblock but couldn't see the warden.
c. The felons pressed into the cellblock but couldn't see the warden.
d. The felons rushed into the cellblock couldn't see the warden.
e. The felons crowded into the cellblock couldn't see the warden.
f. The felons pressed into the cellblock couldn't see the warden.

Crossing the two factors results in six conditions which were incorporated into a counter-balanced design. Each of six stimulus lists contained four items of each type, blocked to ensure that they were evenly distributed through the list. The twenty four critical items were embedded in a matrix of seventy-four filler items. Seven filler items preceded the first critical trial. Four subjects saw each of the six lists.

2.1.3 Equipment

The Skalar model 6500 eye-movement detection system was used to record the subject's eye-movements. This system uses transducers positioned in front of the eye to detect the reflection of infra-red light from the sclera at both the nasal and temporal sides of the iris. The output of the Skalar 6500 is a continuously varying analog signal corresponding to fixation position. The analog signal was sampled each millisecond by an Apple Macintosh computer equipped with a 16 bit analog-to-digital conversion board. Fixations are represented in the raw data by horizontal and vertical coordinates, and starting and ending times. The latter are given as offsets from beginning of the trial, in milliseconds. The former correspond to positions on the computer monitor used to present the stimuli. Stimuli were presented on a 13 inch computer monitor set (nominally) 25 inches from the subjects' eyes. Test materials were presented in a 14 point Courier font such that each character subtends just over 12 minutes of visual arc. Viewing was binocular but eye movements were recorded only for the right eye.

2.1.4 Procedure

Participants were given verbal instructions and a description of the eye-movement method. Because head movements reduce the accuracy of the eyetracker, individually prepared bite-bars and a forehead rest were used to help stabilize head position. Sentences appeared one at a time on a single line of a computer monitor. Before the presentation of each sentence a "fixation point" appeared at the screen position to be occupied by the first character of the sentence. Participants were instructed to focus on the fixation point and then to click a mouse button to call up the sentence. Participants were told that they should read the sentence as they normally would and then click the mouse button as soon as they finished. The action of clicking the mouse button served to erase the sentence from the screen. Thirty of the seventy-four filler trials were followed by a question which the participant responded to by using the mouse to click YES or NO

buttons. The questions' purpose was to ensure that the task of reading for comprehension was being attended to. Every trial was followed by a calibration check. Adjustments to the calibration were carried out occasionally, as necessary.

2.2 Results and Discussion

The analyses presented here are based on first pass fixation durations in the relevant scoring regions of the sentences, as defined in Ferriera and Clifton (1986). First pass fixation duration for a region is the sum of all fixations beginning with the first fixation in that region and ending when a fixation falls outside the region boundaries (either to the left or to the right). The duration of fixations during subsequent visits to a region are not counted in the first pass total. The actual dependent variable used in the analyses was residual first pass reading time (FPRRT). FPRRT is derived by statistically removing the effect of region length, the total number of letters and spaces in a region, on raw first pass fixation times, as recommended in Trueswell, Tanenhaus, and Garnsey (1994). A correction is necessary since region length is not controlled in this experiment and is known to influence fixation time. FPRRT is calculated separately for each subject using a regression with region length as regressor and first pass reading time as dependent variable. The residuals from this calculation become the FPRRT.

For scoring purposes the sentences were divided into five regions. Region 1 contained the subject NP. Region 2 contained the ambiguous verb. Region 3 contained the remainder of the first verb phrase except for the last word. Region 4 included the last word of the first verb phrase and the first two words of the second verb phrase in the MV condition. This region also included the conjunction *but* in the RR condition. Region 5 contained the remainder of the sentence. (8a) shows sample scoring regions for the MV condition, and (8b) for the RR condition.

(8) a. [The felons|rushed|into the|cellblock but couldn't see|the warden.]
1 2 3 4 5

b. [The felons|rushed|into the|cellblock couldn't see|the warden.]
1 2 3 4 5

A single factor ANOVA was performed on region 2, containing the ambiguous verb, testing the effect of frequency bias on fixation times in that region. The effect proved significant in the subject analysis but not in the item analysis ($F_1(2,46)=3.69$, $p < .05$; $F_2(2,46)=2.29$ NS). The mean residual reading times for each condition are shown below:

(9) Average FPRRT in milliseconds at the ambiguous verb for each bias condition.

Bias set	**Mean (sd)**	
past	10.1	(128.4)
equi	9.9	(126.9)
ppart	-16.3	(119.9)

We are specifically interested in the difference between the *past* (past-tense bias) and the *ppart* (past-participle bias) conditions. If syntactic ambiguity is resolved using the same mechanisms as lexical ambiguity, we might predict a subordinate bias effect (see section 1.2 for discussion) to cause fixation time on verbs biased toward the past-participle use to be higher than that on verbs biased toward the past-tense use due to the lexical bias of the verbs in the *ppart* condition conflicting with the contextual bias associated with the *The NOUN VERBed...* frame. However, to the extent that there is any effect associated with frequency bias, its direction is just the opposite.

One possible account of this effect relies on the fact that stem frequency was not completely controlled across the three levels of bias. Rayner and Duffy (1986) showed that word frequency has a reliable inverse relationship to fixation time. The reading times in (9) show that the longest fixation times are on verbs biased toward the simple past tense, the shortest on verbs biased toward the past-participle, with intermediate fixation times on equibiased verbs. The *past* condition has the lowest mean stem frequency (99.92), the *ppart* condition the highest (116.75) and the *equi* condition an intermediate value (105.75).[6] The pattern seen in (9) is coherent if the uncontrolled residue of stem frequency governs fixation times on the ambiguous verbs. This is consistent with proposals in Pinker (1991) who provides arguments and experimental evidence from a lexical naming paradigm (citing Prasada, Pinker, & Snyder, 1990) that frequencies of past-tense forms of regularly inflectional do not influence naming latencies, but see section 3.3 for more discussion.

The pattern of fixation times at the ambiguous verb fails to support a prediction derived from the MacDonald et al. (1994) claim that syntactic ambiguity is reducible to lexical ambiguity. It may be that we do not see a subordinate bias effect because the particular frequency bias associated with the morphological ambiguity examined here is inherently weaker than biases associated with lexical ambiguities like *bank* and *perch*; the frequency bias of the verbs in the past-participle condition is too weak to trigger a subordinate bias effect in the face of an overwhelmingly strong contextual bias toward the simple past interpretation due to the *The NOUN VERBed...* context. Next we turn to an examination of fixation times in Region 4 of the sentences, the region containing the

6 See table (5).

disambiguating material, to see if there is direct evidence of an influence of frequency bias on parsing decisions.

A two factor ANOVA was performed at region 4 to test for effects of frequency bias and continuation type. Region 4 contains the part of the sentence that serves to disambiguate the temporary structural ambiguity that arises due to the morphologically ambiguous verb in region 2. The presence of *but* in this region, as in (7a-c), forces a main-verb reading of the ambiguous verb, while the lack of *but* forces a reduced-relative reading. The main effect of continuation type was significant on both the subject and item analyses [$F_1(2,23)=7.01$, $p < .05$; $F_2(2,23)=8.69$, $p < .05$]. Table (10) shows the mean residual first pass reading time (FPRRT) for the main-verb and reduced-relative conditions.

(10) Average FPRRT in milliseconds at disambiguating region for main verb and reduced-relative continuations.

Continuation type	**Mean (sd)**	
Main Verb	-45.4	(333.1)
Reduced Relative	32.2	(329.0)

The main effect of continuation type in the experiment reported here, with elevated reading times in the reduced-relative condition, replicates the findings of previous studies examining the reduced-relative garden-path sentence (cf. Ni, Crain, & Shankweiler 1996).

The main effect of frequency bias was non-significant on both subject and item analyses ($F_1<1$; $F_2<1$). The interaction of continuation type and frequency bias proved marginal in the subject analysis but was not significant in the item analysis ($F_1(2,46)=2.90$, $p=.065$; $F_2(2,46)=1.71$ NS). That the interaction even approaches significance lends support to the MacDonald et al. hypothesis.[7] Table (11) shows mean FPRRT for the interaction with standard deviations in parentheses. It is clear that the difference between the MV and RR conditions is considerably larger at the *past* level of frequency bias (verbs that have an *-ed* form strongly biased toward simple past tense usage) than at either of the other two levels.

7 The strength of the manipulation of frequency bias in this experiment might be questioned, but table (5) shows it to be of greater magnitude than the range of differences found in the studies examined by MacDonald et al. (1994). I assume that the manipulation is adequate to evoke the effect under investigation.

(11) Mean FPRRT in milliseconds (sd) for continuation type by frequency bias at the disambiguating region.

	Continuation Type				
Bias Set	**Main Verb**		**Reduced Relative**		**Difference**
past	-95.1	(324.7)	68.4	(345.0)	163.5
equi	-1.5	(335.0)	29.2	(308.1)	30.7
ppart	-39.5	(336.1)	-1.0	(332.6)	38.5

Three single factor ANOVAs were performed to test the simple effects of continuation type at each level of frequency bias. The effect of continuation type at the *past* level of bias is easily significant ($F_1(1,23)=10.36$, $p<0.0038$; $F_2(1,23)=21.71$, $p<0.0001$), even with reasonable adjustments to α to control the family-wise error rate, while the effect of continuation type at the other two levels of bias fails to approach significance (all Fs < 1).

3 General Discussion

In spite of the marginal status of the continuation-by-bias interaction, the pattern of means in (11) provides evidence that a verb's relative frequency of simple-past versus past-participle use influences initial parsing decisions in the reduced-relative/main-verb ambiguity.[8] This supports the empirical claim of MacDonald et al. (1994). The question arises as to whether this finding poses a serious challenge to the Referential Model of sentence processing. Before attempting to answer the question a review of the fundamental claims of the model is appropriate.

3.1 The Referential Model

The Referential Model takes a modular view of language processing in which sub-components of the language faculty that operate in distinct domains (phonological, syntactic, and semantic) function in a largely independent manner, although highly constrained interaction between the modules is possible. There are four basic principles of the model, set out in Crain and Steedman (1985), and refined in Ni (1991), and Ni, Crain, and Shankweiler (1996).

8 The possibility that frequency bias does not influence initial parsing decisions, but only comes into play when re-analysis is necessary, once the parser has been garden-pathed, can be ruled out. If this were the case then frequency bias should have no effect on reading times in the disambiguating regions of sentences which do not contain a garden-path, e.g. (7a-c). Table (11), MV column, shows that frequency bias does influence reading times in the disambiguating region of non-garden path sentences. This indicates that frequency bias exerts an early influence on parsing decisions.

First, in the case of structural ambiguity, all possible structures are constructed by the syntax, in parallel. Second, interaction between syntactic and semantic processors occurs as the semantic processor evaluates structures proposed by the syntax on a nearly word-by-word basis. Third, the semantic processor attempts to choose from among the available structures by evaluating how well each fits a mental model of the discourse. The syntactic structure entailing the fewest extensions to the mental model is adopted and others are discarded. This necessarily involves a comparison of all available structures. Both general world knowledge and specific knowledge of the discourse model can influence decisions made by the semantic processor. Priority is given to discourse knowledge as, by hypothesis, this is information available internal to the language facility. Accessing world knowledge is posited to require going outside the language faculty, and so to be much more demanding of resources. The Referential Model holds that the reduced-relative/main-verb ambiguity is (in the null context) resolved by reference to the relative complexities of the presuppositions entailed by the reduced-relative and main-verb structures. Consider (7d) repeated as (12).

(12) The felons rushed into the cellblock couldn't see the warden.

When a sentence like (12) is encountered out of context the parser actively constructs a mental representation that is consistent with it. On encountering the subject NP *The felons...* the syntactic component of the parser generates the appropriate structure, while the semantic component creates a mental model in which there exists a set of felons. When the ambiguous verb *rushed* is encountered the syntactic processor constructs (at least) two structures; in one the verb heads a reduced relative clause and in the other it is a past tense main verb. These structures are made available to the semantic processor for evaluation. The reduced-relative reading requires that the set of felons already in the mental model be partitioned into those that were rushed and those that were not, while the main-verb reading requires no such partition. For (12) the semantic processor will adopt the main-verb reading because doing so is computationally less demanding than adopting the reduced-relative reading.[9] Crain and Steedman (1985) formulate the relevant principle as (13).

(13) *principle of parsimony*
If there is a reading that carries fewer unsatisfied but consistent presuppositions or entailments than any other, then, other criteria of plausibility being equal, that reading will be adopted as the most plausible by the hearer, and the presuppositions in question will be incorporated into his or her [mental] model.

After adopting a structure in which *rushed* is a main verb, the parser eventually encounters *couldn't see*, the verb cluster containing the actual main verb of the sentence.

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9 As discussed in section 1.1 it is possible to change which structure the parser prefers by manipulating the referential/semantic properties of the sentence, as by substituting *only* for *the*. See Ni, Crain, and Shankweiler (1996) for details.

It is unable to incorporate this material into the existing analysis and so is forced to reanalyze the sentence. The Referential Model predicts the region of a reduced-relative garden-path sentence containing the second verb (the actual main verb) will be a locus of processing difficulty. This prediction is consistent with the typical finding, in eye-movement studies, of elevated fixation times at the region of the sentence containing the actual main verb, relative to the same region of a sentence in which the ambiguous verb actually is a main verb. The model provides a principled account of the reduced-relative garden path phenomenon in which the alternative syntactic structures are evaluated based on the complexity of the extensions to a mental discourse model entailed by the structures. The structure requiring fewest extensions to the mental model is adopted by the parser. In the next section I will develop an extension to the model that explains the influence of frequency bias on parsing decisions, while maintaining this 'least effort' parsing principle.

3.2 Extensions to the Referential Model

The new result to come out of this study is that the relative frequency of past-tense versus past-participle use of the *-ed* form of a verb serves to modulate the strength of the reduced-relative garden-path. In this subsection I will compare two distinct extensions to the Referential Model that might be used to accommodate this result.

The first account assumes that frequency biases associated with the verb are directly available to the semantic processor, and that these biases influence the processor's choices in selecting from among the structures made available by the syntax. We could stipulate that principle (13) allows for this with frequency bias falling under the rubric of 'other criteria of plausibility.' The relative frequency with which a particular *-ed* form occurs as past-tense versus past-participle would serve as an index as to the plausibility of that form occurring in a particular linguistic structure, main-verb versus reduced-relative. In the course of deciding on a particular structure the semantic processor would consider both (a) the relative computational complexity associated with the two structures, as discussed in section 3.1, and (b) the relative frequency with which a verb occurs as a past-tense versus a past-participle. The problem with this account is that frequency is not the sort of information one would like to see a component of the grammar specialized for semantic processing make use of.[10] Given conventional

10 An alternative more consistent with the posited operational domain of the semantic processor within the Referential Model is that some unknown semantic properties of the verb influence parsing decisions, and these semantic properties are reflected in the frequency of the verbs' past-participle uses. The range of verbal semantic properties potentially relevant to parsing decisions of the semantic processor has yet to be fully explored, although 'goodness of thematic fit' as discussed in Tanenhaus, Carlson, and Trueswell (1989), and subsequent work plausibly falls into this category.

A first move toward testing this hypothesis with respect to other lexical semantic properties would be to see whether the verbs in each of the three frequency based categories used in this study can be differentiated on semantic grounds given some relatively well defined theory of lexical semantics like that of Jackendoff (1990). However, the present experiment was not intended to test this possibility, and so I leave this avenue aside as a possible direction for future research.

assumptions about the architecture of a modular theory of parsing, it does not seem reasonable to allow for frequency biases to influence parsing decisions directly. Therefore I will set aside this possibility in favor of a conceptually more pleasing alternative.

If we take seriously the MacDonald et al. (1994) hypothesis that morphological ambiguity is handled in essentially the same manner as lexical ambiguity, and place that hypothesis in the context of the Referential Model we find that there is no necessary conflict between the two. There is much evidence to show that word frequency and word sense frequency influence lexical access latency. Some of the eye-movement research that bears on this issue was discussed in section 1.2. Evidence from other experimental paradigms, like cross modal lexical priming (Onifer & Swinney, 1981; Simpson & Burgess, 1985), also supports this idea. Following proposals stemming from these lines of research, I make what I take to be the uncontroversial assumption that frequency determines the latency with which word senses become available to post access processes.[11] In order to make use of the temporal sequencing of lexical access to explain the data from the present experiment it is necessary to assume that this sequencing applies to morphological ambiguities as well as to lexical ambiguities. I assume that the past-tense and past-participle uses of the *-ed* forms of regular verbs are accessed by the syntax in a specific temporal sequence determined by their relative frequencies, with the more frequent use being accessed first.[12]

Next, we need to partly rethink the operation of the language processor as conceived in the Referential Model. A basic tenet of the model is that primary responsibility for resolving structural ambiguity lies with a semantic component of the grammar that attempts to select from among alternative syntactic structures that are present in memory simultaneously. So representational parallelism is a necessary component of the model. Both representational and computational parallelism, at the level of syntax, have been explicitly present in the theory since Crain and Steedman (1985:328-9) who suggest that all possible syntactic structures are constructed simultaneously. Ni, Crain, and Shankweiler (1996) also adopt this assumption. But computational parallelism is not a necessary component of the model. In order for the semantic processor to evaluate and choose from among different syntactic possibilities these possibilities must be available simultaneously for comparison, but this does not

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11 I make no assumption here as to whether context interacts with frequency in determining access latencies, or whether context only influences post-access processes, *integration* in the sense of Rayner and Frazier(1989), see section 1.2.

12 It should be observed that this position may conflict with that of Pinker (1991) (also Prasada & Pinker, 1993; Kim, Pinker, Prince, & Prasada, 1991)where it is argued that frequencies associated with the inflected members of regular paradigms, at least in the case of regular past-tense verbs, are irrelevant to lexical access latencies. See the next section for some discussion.

entail that all structures come into existence simultaneously. The logical alternative is that the syntactic module builds a single representation at a time.[13]

One further assumption is needed before proceeding. According to the Referential Model, which I take as a point of departure, a mental model of the discourse must be modified in order for the parsing mechanism to adopt a reduced-relative reading (in the null context), while no such modification is necessary to adopt a main verb reading (see section 3.1). The difference between the two structures, in terms of the computational resources necessary to accommodate them, accounts for the preference that the processor shows for main verb readings. Simply put, the processor takes the path of least effort. The key assumption that I make is that modifications to the discourse model necessary to adopt the reduced-relative reading take time, more time than is necessary to adopt the main-verb reading (call the increment of time a step). In other words, I assume that modifying the discourse model takes longer than not modifying it. Now we are ready to look at how the reduced-relative main-verb ambiguity might fare under these assumptions.

First let us look at the case where the simple past use of the verb is more frequent than the past participle use. The structure appropriate to the main verb will be built up by the syntax first. When that structure becomes available to the semantic module (at time 0), it is tested for consistency with the discourse model (time 1), and found to be consistent. Therefore the reading is quickly and easily adopted (time 2) by the semantic module, possibly before the reduced-relative structure is even available.[14] This predicts a typical garden path effect when the main verb reading of the ambiguous verb turns out to be inconsistent with the rest of the sentence.

Next, we look at the case where the past-participle use of the verb is more frequent than the past-tense use. The reduced-relative structure appropriate to the past-participle will be processed by the syntax first. When the structure becomes available to the semantic processor (at time 0), it is tested for consistency with the discourse model (time 1). In this case the semantic module is unable to adopt the structure quickly (at time 2) because it is not consistent with the discourse model. The model must be modified before the reading can be adopted. In the meantime the syntactic processor is at work producing the structure appropriate to the less frequent past-tense use of the verb. If this main verb structure becomes available before modifications to the discourse model are

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13 This modification to the Referential Model is not necessary to my purposes here, but as it is a simplifying assumption I will adopt it. An alternative is that a parallel syntactic processor begins to build each structure as soon as the morphological verb form (past-tense or past-participle) appropriate to it becomes available, or reaches threshold. What is important in the present context is that the latencies (sequence) with which syntactic structures become available to the semantic module are governed by access latencies due to frequencies associated with particular verb forms.

14 For concreteness I assume, following Rayner and Frazier (1989), that successful integration of a word sense into the existing structure pre-empts access to subordinate senses of the word, but see Pacht and Rayner (1993) for a different view of pre-emptive lexical access.

complete its presence pre-empts those modifications. The new structure is evaluated and found to be consistent with the existing discourse model and so adopted. However, if modifications to the discourse model are completed before the main verb structure becomes available then the reduced-relative reading is adopted.

Under this proposal the reduced-relative structure is unlikely to be considered if the *-ed* form of the ambiguous verb is biased toward past-tense use. On the other hand, if the verb bias is in the other direction the reduced-relative structure becomes a viable competitor. In this case the reduced-relative structure is adopted at least some of the time. In the experiment described here a verb bias toward past-participle use was found to reduce the garden-path effect causing convergence in the reading times at the disambiguating region of main-verb and reduced-relative sentences. This is just the pattern expected once reading times are averaged over items and subjects.

3.3 Integrating the parts

In this section I will first briefly discuss a possible conflict between the present proposal and proposals in Pinker (1991) and subsequent work by Pinker and colleagues, and then I will propose a resolution for an inconsistency between the preceding section and section 2.2, where I speculated that stem frequency might account for the pattern of fixation times seen at the ambiguous verb.

Pinker (1991) argues for a lexical/morphological system consisting of an associative lexical network (lexicon) which feeds into a morphological module. The module generates regularly inflected forms by applying morphological rules to stems; members of regular inflectional paradigms do not exist as independent lexical items, but are generated by the morphology from a stem or base form. In the case of the past-tense forms of regular verbs the rule generates the inflected form by concatenating the affix *-ed* onto the stem. This contrasts with irregular past-tense verbs which, by hypothesis, do exist as independent items in the lexicon connected to their 'stems' through associative links. In Pinker's model the lexicon is an associative network that feeds into a discrete morphological component of the grammar.

Pinker predicts that frequency biases associated with members of regular inflectional paradigms ought to be irrelevant to lexical access latencies. He contends that access latencies for all members of a regular paradigm are governed by stem frequency alone as, by hypothesis, that is the only member of the paradigm that exists in the lexicon and so is the only member for which frequency information can be stored. He provides some experimental evidence from lexical decision and naming tasks, citing Prasada, Pinker, and Snyder (1990), showing that verbs with regular versus irregular past tense forms do differ in the predicted manner. For example, naming latencies for regular past tense verb forms were found to be independent of the frequency of the past tense form, while naming latencies for irregular past tense forms were found to be dependent on the frequency of the past tense form.

The present experiment, with all verbs regularly inflected, provides evidence that in at least some cases members of regular paradigms do show frequency dependent effects. This would appear to contradict Pinker's prediction that such effects should not be found in regular inflectional paradigms. To be specific, this study provides evidence of frequency effects due to the relative frequencies of past-tense versus past-participles. However, I have not demonstrated an effect due specifically to past-tense frequency. The present result is consistent with Pinker's experimental findings in the event that the frequency effect seen here is due to past-participle frequency alone, which would imply, if Pinker and colleagues are on the right track, that past-participles exist as separate lexical entries apart from their stems (unlike regular past-tense forms). Now I turn to the pattern of reading times seen at the ambiguous verb itself, seen in (9).

In section 2.2 I speculated that relative frequency of past-tense versus past-participle has no effect on fixation times at the ambiguous verb itself, but that stem frequency modulates fixation time ambiguous *-ed* verb forms (table 9). This was by way of accounting for the lack of the 'subordinate bias effect' seen in lexical ambiguities (see section 1.2). The suggestion would seem to contradict the model developed later (section 3.2) where it is assumed that the past-tense and past-participle verb forms are accessed in order of their relative frequencies, with the more frequent being accessed first. However, there is a variant of this hypothesis that is consistent both with the Pinker proposal and with the proposal in section 3.2. First, I adopt the Pinker claim that regular past-tense forms are accessed at some fixed latency (or at least the latency is independent of past-tense frequency), and then I assume that the access latency for past-participles varies with frequency. Now, the account developed in section 3.2 goes through if the access latency of low frequency past-participles is longer than the fixed latency of the homophonous past-tense forms, while the access latencies of high-frequency past-participles is shorter than that for the homophonous past-tense forms.

The pattern of fixation times in (9) can then be explained as follows. Access latencies for past-tense forms are independent of past-tense frequency, but access latencies for past-participle forms depend on past-participle frequency. In the case where past-participle frequency is low (*past* condition) the frequency independent latency of the past-tense form wins the race and we see (relatively long) fixation times on the ambiguous verb reflecting the access latencies due to the past-tense form. But, when the past-participle frequency is high (*ppart* condition) enough to reduce access times for past-participle forms below that of the past-tense form then we see low fixation times on the ambiguous verb reflecting fast access of past-participle forms. The fact that the fixation times on verbs in the *equi* condition are similar to fixation times on verbs in the *past* condition can be taken as an indication that past-participle frequencies in that condition are not high enough to reduce access latencies for past-participles substantially below those of past-tense forms, although they may be nearly equal as indicated by an ameliorated garden-path effect for reduced-relative sentences containing a verb in the *equi* condition.

4 Conclusion

I provide evidence that the relative frequency of past-tense versus past-participle verb use has a real effect on parsing sentences containing a main-verb/reduced-relative temporary ambiguity. This effect needs to be accommodated in any theory human sentence processing. The Referential Model of processing is shown to be able to accommodate the effect with a minimum of elaboration. The model advocated here assumes a lexicon in which words are represented in an associative network as in Pinker (1991). I also adopt the assumption that the latency with which morphological variants of verbs, past-tense versus past-participle, are available for syntactic processing is governed, at least in part, by frequencies associated with those variants. Finally, I assume that the computational complexities associated with processing particular structures have temporal consequences. This set of assumptions provides for a simple account of the effect of morphological frequency bias on parsing decisions. How strong this bias is relative to other established influences on parsing decisions remains to be seen. Future research will determine this empirically by combining the factor of frequency bias with other factors, such as the referential manipulation of Ni, Crain, and Shankweiler (1996) or the thematic manipulation of Trueswell, Tanenhaus, and Garnsey (1994).

Appendix

Test Frames: Numbers in parentheses indicate the verb set used in the frame. The presence versus absence of *but* was alternated in each frame.

1. The felons (1)ed into the cellblock but couldn't see the warden.
2. The citizen (2)ed an award but is unhappy with the mayor.
3. The citizens (3)ed to draw up a petition but agreed on very little.
4. The student (4)ed to take the test early but wasn't really ready.
5. The managers (5)ed sick leave but weren't allowed to take it.
6. The knife (6)ed from improper use but has been replaced.
7. The students (7)ed into the classroom but couldn't find seats.
8. The company (8)ed for the shipment but filed bankruptcy recently.
9. The detective (9)ed all week but wouldn't comment on the crime.
10. The child (10)ed this evening but wouldn't sleep quietly.
11. The workers (11)ed to picket the factory but couldn't get inside.
12. The troop (12)ed to discourage pursuit but got lost in the woods.
13. The chisel (6)ed against the stone but is still okay to use.
14. The pact members (5)ed trade permits but charged high import taxes.
15. The mediator (4)ed to hear the case but wasn't allowed to do so.
16. The students (3)ed to help with fund-raising but didn't get much done.
17. The union (2)ed a compromise but is angry with management.
18. The man (1)ed into the busy emergency room but wasn't really sick.
19. The soldiers (12)ed to defend the hill but were badly defeated.
20. The urbanites (11)ed to recall the mayor but were too divided

21. The baby chimp (10)ed this morning but whimpered fitfully.
22. The children (9)ed on Monday but won't be tested until Friday.
23. The teenager (8)ed for the pizza but lost his wallet.
24. The passengers (7)ed onto the small plane but were very unhappy

Verbs with Francis and Kučera (1982) counts for stem, past tense, and past participle of verbs used in the study, as well as the bias set for each verb.

SET	VERB	STEM	PAST	PPART	BIAS SET
1	rush	42	20	7	past
1	crowd	39	8	24	ppart
1	press	82	12	16	equi
2	refuse	91	44	16	past
2	present	158	16	66	ppart
2	offer	217	43	40	equi
3	gather	66	22	10	past
3	unite	495	3	16	ppart
3	enlist	17	5	6	equi
4	beg	34	13	0	past
4	prepare		163	12	90 ppart
4	request	29	5	7	equi
5	promise	68	26	19	past
5	grant	78	7	49	ppart
5	issue	72	20	30	equi
6	crack	41	11	6	past
6	chip	10	1	3	ppart
6	dull	4	1	2	equi
7	hurry	45	18	5	past
7	jam	10	1	7	ppart
7	pack	44	7	12	equi
8	owe	34	12	3	past
8	charge	82	17	38	ppart
8	pay	325	50	94	equi
9	watch	209	68	13	past
9	observe	120	15	59	ppart
9	study	163	34	44	equi
10	rock	20	7	1	past
10	wash	83	10	25	ppart
10	nurse	17	0	0	equi
11	push	102	31	22	past
11	organize	80	5	52	ppart
11	press	82	12	16	equi
12	move	447	138	43	past
12	divide	83	11	44	ppart
12	offer	217	43	40	equi

References

Carpenter, P.A, & M.A. Just. 1983. "What Your Eyes Do While Your Mind Is Reading," in K. Rayner (ed.), Eye Movements in Reading: perceptual and language processes, New York: Academic Press.

Connine, C., F. Ferreira, C. Jones, C. Clifton, & L. Frazier. 1984. "Verb Frame Preferences: descriptive norms," Journal of Psycholinguistic Research 13(4), 307-319.

Crain, S., W. Ni, D. Shankweiler, L. Conway, & D. Braze. 1996. "Meaning, Memory, and Modularity," MIT Occasional Papers in Linguistics 9: Proceedings of the NELS 26 Sentence Processing Workshop, 27-44. Cambridge MA: MITWPL.

Crain, S., & M. Steedman. 1985. "On Not Being Led up the Garden Path: the use of context by the psychological parser," in D.R. Dowty, L. Karttunen, & A.M. Zwicky, eds. Natural Language Parsing: Psychological, Computational, and Theoretical Perspectives. Cambridge: Cambridge University Press.

Daneman, M. & P. Carpenter. 1980. "Individual Differences in Working Memory and Reading," Journal of Verbal Learning and Verbal Behavior 19, 450-466.

Duffy, S., R. Morris, & K. Rayner. 1988. "Lexical Ambiguity and Fixation Times in Reading," Journal of Memory and Language 27(4), 429-446.

Ferriera, F., & C. Clifton. 1986. "The Independence of Syntactic Processing," Journal of Memory and Language 25(3), 348-368.

Francis, W.N., & H. Kučera. 1982. Frequency Analysis of English Usage: lexicon and grammar. Boston: Houghton Mifflin.

Frazier, L. 1979. On Comprehending Sentences: syntactic parsing strategies. University of Connecticut, PhD. dissertation.

Frazier, L. & K. Rayner. 1982. "Making and Correcting Errors During Sentence Comprehension: eye movements in the analysis of structurally ambiguous sentences," Cognitive Psychology 14(2), 178-210.

Frazier, L. & C. Clifton. 1996. Construal. Cambridge, MA: MIT Press.

Jackendoff, R. 1990. Semantic Structures. Cambridge, MA: MIT Press.

Kim, J.J., S. Pinker, A. Prince, & S. Prasada. 1991. "Why No Mere Mortal Has Ever Flown Out to Center Field," Cognitive Science 15, 173-218.

MacDonald, M.C. 1994. "Probabilistic Constraints and Syntactic Ambiguity Resolution," Language and Cognitive Processes 9(2), 157-201.

MacDonald, M.C., N.J. Pearlmutter, & M.S. Seidenberg. 1994. "Syntactic Ambiguity Resolution as Lexical Ambiguity Resolution," in C. Clifton, L. Frazier, & K. Rayner, eds, Perspectives on Sentence Processing. Hillsdale, NJ: Lawrence Erlbaum Assoc.

Ni, W. 1991. Referentiality and Garden Path Phenomena. University of Connecticut, PhD. dissertation. published by University of Connecticut Working Papers in Linguistics.

Ni, W., S. Crain, & D. Shankweiler. 1996. "Sidestepping Garden Paths: The contributions of syntax, semantics, and plausibility in resolving ambiguities," Language and Cognitive Processes 11(3), 283-334.

Onifer, W. & D. Swinney. 1981. "Accessing Lexical Ambiguities During Sentence Comprehension: Effects of frequency of meaning and contextual bias," Memory and Cognition 9(3), 225-236.
Pacht, J., & K. Rayner. 1993. "The Processing of Homophonic Homographs During Reading," Journal of Psycholinguistic Research 22(2), 251-271.
Pinker, S. 1991. "Rules of Language." Science 253(5019), 530-35.
Prasada, S., & S. Pinker. 1993. "Generalization of Regular and Irregular Morphological Patterns," Language and Cognitive Processes 8(1), 1-56.
Prasada, S., S. Pinker, & W. Snyder. 1990. Paper presented at the 31st Annual Meeting of the Psychonomic Society. New Orleans, November 16-18, 1990.
Rayner, K., & S.A. Duffy. 1986. "Lexical Complexity and Fixation Times in Reading: effects of word frequency, verb complexity, and lexical ambiguity," Memory and Cognition 14(3), 191-201.
Rayner, K. & L. Frazier. 1989. "Selection Mechanisms in Reading Lexically Ambiguous Words," Journal of Experimental Psychology: Learning, Memory, and Cognition 15(5), 779-790.
Simpson, G.B. & C. Burgess. 1985. "Activation and selection processes in the recognition of ambiguous words," Journal of Experimental Psychology: Human Perception and Performance 11(1), 28-39.
Taraban, R. & J.L. McClelland. 1990. "Parsing and Comprehension: a multiple constraint view," in D.A. Balota, G.B. Flores d'Arcais, and K. Rayner (ed.s), Comprehension Processes in Reading. Hillsdale, NJ: Erlbaum.
Tanenhaus, M.K., G.N. Carlson, & J.C. Trueswell. 1989. "The Role of Thematic Structures in Interpretation and Parsing," Language and Cognitive Processes 4(3-4), 211-234.
Tanenhaus, M.K. & J.C. Trueswell. 1995. "Sentence Comprehension," in J. Miller & E. Eimas (eds.), Handbook of Perception and Cognition. New York: Academic Press.
Trueswell, J.C., M.K. Tanenhaus, & S.M. Garnsey. 1994. "Semantic Influences on Parsing: use of thematic role information in syntactic ambiguity resolution," Journal of Memory and Language 33(3), 285-318.
Trueswell, J.C., & M.K. Tanenhaus. 1994. "Toward a lexicalist framework of constraint based syntactic ambiguity resolution," in C. Clifton & L. Frazier (eds.), Perspectives on Sentence Processing. Hillsdale, NJ: Erlbaum Associates.

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