

Parafoveal and Semantic Effects on Syntactic Ambiguity Resolution

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Abstract

Subjects were presented with strongly past-participle biased sentences such as, *The portrait sketched by the tree was very beautiful*, in a self-paced reading time task. Sentences were displayed two words at a time, (e.g., *The portrait / sketched by ...*) so that the verb and the disambiguating preposition were read together. In Experiment 1, a set of materials constructed to minimize the past-tense bias with an inanimate NP was compared with a less constraining set of sentences. The syntactic gardenpath usually associated with the reduced-relative construction was not present with the more constraining materials, but was with the less constraining NP sentences. In Experiment 2, using only the more constraining materials, preposition length was manipulated so that subjects read sentences with both short (i.e., *by*) and long (i.e., *underneath*) prepositions. No syntactic gardenpaths occurred with sentences with the past-participle bias and short prepositions; however, when the same sentences were read with the long prepositions, the syntactic gardenpath was present. This result is inconsistent with a deterministic parser. We expand on our previous proposals that the parser must be able to take into account both semantic and verb-form information, as well as, the amount of disambiguating information (in the form of a preposition) that can be integrated with the ambiguous verb.

Introduction

A challenge for models of language comprehension is describing the nature of the interaction among the various components in the comprehension process. It is uncontroversial that language can be described by a set of subsystems (i.e., syntax, semantics, phonology, morphology, pragmatics), but there has been considerable controversy about the degree of correspondence between these linguistic subsystems and the actual process of language comprehension. The resolution of lexical and syntactic ambiguity has played a crucial role in this debate due to the problems that ambiguity presents for the efficient functioning of the language processor. This paper explores the degree to which syntactic and visual information can guide the syntactic analysis of reduced-relative sentences that typically result in confusion for the reader due to a misassignment of the structural parts of a sentence, commonly referred to as a gardenpath

Why Gardenpaths?

Explanations vary on whether or not (and under what conditions) a reader will experience a gardenpath. Frazier

(1978) and her colleagues (Ferreira & Clifton, 1986) have presented considerable evidence that the parser uses a deterministic strategy. They suggest that the parsing mechanism is insensitive to contextual information, since it would rely only on structural cues. One of these strategies, Minimal Attachment, proposes that words are attached to a phrase marker using the fewest possible syntactic nodes permissible by syntactic rules. Thus, a past-tense analysis is to be preferred, because its analysis is simpler than the past-participle form.

Ferreira and Clifton (1986) reasoned that earlier failures to demonstrate that sentential context could override this Minimal Attachment strategy may have been due to the weak constraints offered by the context. As a stronger manipulation, they varied the animacy of the first NP, so that the implausibility of an inanimate NP in agent position should eliminate the gardenpath in (1b), but not in (1a).

- (1a.) The defendant examined by the lawyer turned out to be unreliable.
- (1b.) The evidence examined by the lawyer turned out to be unreliable.

They found that animacy of the first noun phrase had no effect on reading times at either the by-phrase or the second verb. It seems, then, that the Minimal Attachment preference results in a gardenpath regardless of the animacy information in the first NP.

Previously, we (Burgess & Tanenhaus, 1992) replicated Ferreira and Clifton's results using a word-by-word reading paradigm in which only a single word was present at a time. Although the semantic constraint offered by the sentential context was stronger than in the sentences used by Ferreira and Clifton, both sets of stimuli demonstrated the typical gardenpath effect in both the animate and inanimate conditions. However, the word-by-word reading method differed from that of Ferreira and Clifton in that the disambiguating preposition was not read with the verb since each word was read separately. Burgess and Hollbach (1988) demonstrated in a computer simulation that the strength of the syntactic gardenpath was a function of multiple constraints including the bias of the verb, the extent of a delay in the disambiguation of the morphologically ambiguous verb, as well as the possibility of contextual constraints. In Experiment 1, we test the hypothesis that the

combination of NP-bias and reading the disambiguating preposition with the verb will allow the typical reduced-relative gardenpath to be avoided.

**Experiment 1 - Agency Manipulation:
2-Word by 2-Word Reading**

Stimuli. Sixteen sentences were selected that had a strong bias toward a past-participle interpretation. In a previous set of studies (Burgess & Tanenhaus, 1992), subjects completed the initial NP+V fragments of these sentences as a past-participle interpretation 85% of the time. The sixteen sentences used in Ferreira and Clifton's (1986) Experiment 1 were also included in this experiment, as a set of less constraining stimuli, and these sentences had a past-participle interpretation only 58% of the time.

Each subject saw four sentences in each of the four conditions: past-tense biased (reduced) [2a], past-tense biased (unreduced) [2b], past-participle biased (reduced) [2c], past-participle biased (unreduced) [2d].

- (2a.) The man paid by the parents was unreasonable.
- (2b.) The man who was paid by the parents was unreasonable.
- (2c.) The ransom paid by the parents was unreasonable.
- (2d.) The ransom that was paid by the parents was unreasonable.

Four lists were formed so that any subject would see a critical verb in only one sentence. Sentences were presented two words at a time. Thus, a sentence would be segmented for purposes of presentation as follows: Det Noun / Verb1 prep / Det Noun / Verb2 word / ... This segmentation allows for the ambiguous verb and the disambiguating preposition to be presented together. Forty-four filler sentences were added in order to make it unlikely that the subject would incorporate some processing strategy that would be particularly sensitive to the syntactic constructions used in this experiment.

Procedure. Subjects were forty native English speakers from the University of Rochester who had normal or corrected-to-normal vision. A two-word by two-word self-paced reading task was used ('moving window' task, see Just, Carpenter, & Woolley, 1982). The subject began a trial by pressing a button which presented the trial number. A second button press brought up a complete set of dashes such that the information concerning sentence and word length was present in the form of dashes that corresponded to each letter position. The subject pressed a different button with the index finger of the right hand in order to see each set of two words in the sentence. As each successive group of two words appeared, the previous words were replaced by dashes. The duration for which each two-word

group appeared was recorded from the onset of the word to its associated button press. Screen width was set to 80 columns. In the event that a critical sentence was longer than 80 columns, the break point was the same for reduced as unreduced versions.

Results. Reading time differences between the reduced and unreduced conditions are shown in Figure 1a and 1b. The experimental design was a 2 (sentence set) x 2 (NP-bias) x 2 (location in sentence: Verb+Prep and Det+Noun) x 2 (reduction). Sentence set refers to the more constraining sentences that we constructed or to the less constraining set used by Ferreira and Clifton. The crucial four-way interaction was obtained, $F(1,39) = 4.20, p = .048$.

Ferreira and Clifton's Materials. There was a main effect for reduction, $F(1,39) = 10.08, p = .003$. Reading times in the reduced condition were longer (404 ms/2 words) than in the unreduced condition (380 ms/2 words). Since there was

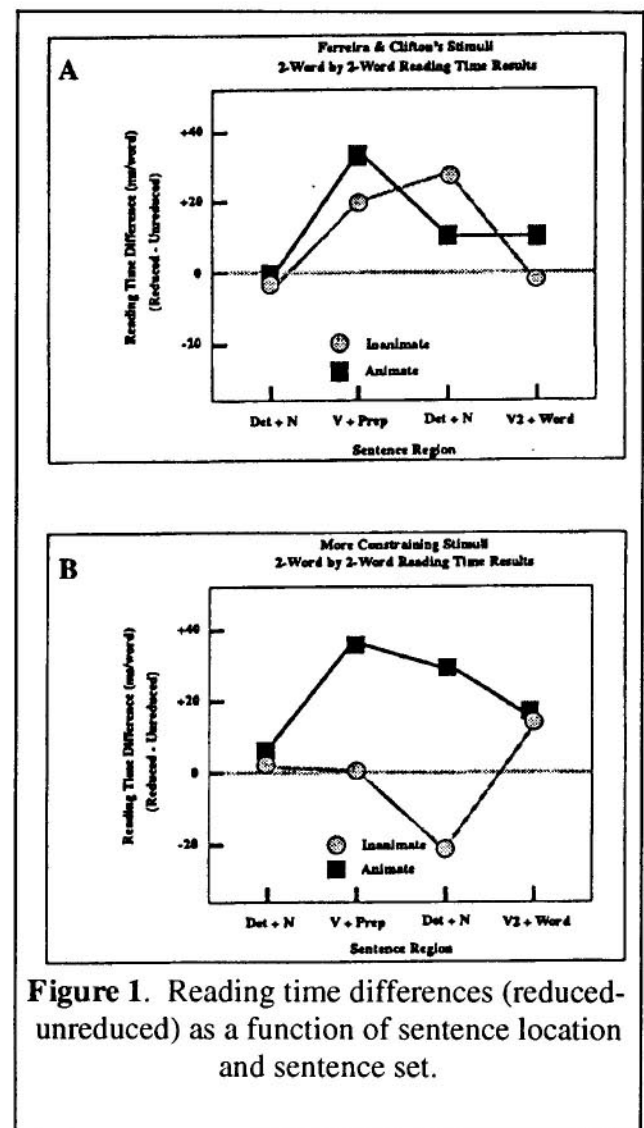


Figure 1. Reading time differences (reduced-unreduced) as a function of sentence location and sentence set.

no reduction x sentence location interaction, the gardenpath effect spans both sentence locations. The pattern of most interest with the Ferreira and Clifton sentences, however, is that both NP-bias conditions result in a gardenpath effect at the Verb+Prep and Det+Noun locations. This is consistent with Ferreira and Clifton's original results, namely, that the semantic bias of the noun had no differential effect on the parsing decision.

More Constraining Materials. The two-way interaction between reduction and NP-bias obtained, $F(1,39) = 6.84, p = .013$. Simple main effects tests indicate that, for past-tense biased NPs, reading times in the reduced condition were longer (437 ms/2 words) than in the unreduced condition (403 ms/2 words), $F(1,39) = 12.56, p = .001$. For the more constraining materials, then, the past-tense biased (animate) NPs result in the typical gardenpath. Of more interest, of course, are the reading times in the past-participle biased (inanimate) condition. There we find no interaction, $ps > .18$, between reduction and sentence location, nor is there a main effect of reduction, $ps > .29$ (reduced = 404 ms/2 words; unreduced = 415 ms/2 words). Thus, when the Verb+Prep is preceded by a past-participle biased NP, there is no gardenpath.

Discussion

When the verb and the disambiguating preposition are presented together with the more constraining NPs, the past-participle biased NP allowed the parser to avoid the gardenpath. However, the gardenpath *was* present with Ferreira and Clifton's (1986) sentences at Verb1+Prep and Det+Noun locations, replicating their original result using their stimuli.

There are a variety of sources of constraint that will allow a correct interpretation to emerge in the comprehension process, apparently without the cognitive overhead of a gardenpath. Burgess and Hollbach (1988) have proposed that the availability of the past-participle form of the verb is very brief compared to that of the past-tense form, given its learning history. Such a proposal is consistent with the earlier result showing that the preposition must be immediately available as a cue with the verb in order for a gardenpath to be avoided. The present experiment attempts to further manipulate these constraints by demonstrating that the more semantically constraining sentences that *did not* gardenpath in Experiment 1, *will* exhibit a gardenpath when the length of the disambiguating preposition is increased, and, thus, result in a delay in the integration of the prepositional cue with the ambiguous verb.

Experiment 2 Manipulating Preposition Length

Stimuli and procedure. Each subject saw four sentences in each of the four conditions: short preposition (reduced)

[3a], short preposition (unreduced) [3b], long preposition (reduced) [3c], long preposition (unreduced) [3d].

- (3a.) The portrait sketched by the tree was very beautiful.
- (3b.) The portrait that was sketched by the tree was very beautiful.
- (3c.) The portrait sketched underneath the tree was very beautiful.
- (3d.) The portrait that was sketched underneath the tree was very beautiful.

Subjects were 32 native English speakers from Syracuse University and the University of California, Riverside. The procedure was identical to Experiment 1.

Results. The experimental design was a 2 (Preposition: long or short) x 2 (location in sentence: NP, Verb+Prep) x 2 (reduction: reduced or unreduced relative clause). Mean reading times for the design can be seen in Table 1. There was a main effect of position, $F(2,60) = 23.63, p < .001$, of preposition length, $F(1,60) = 29.56, p < .001$, and of reduction, $F(1,60) = 6.52, p < .02$. Position interacted with preposition length ($p < .001$), and preposition length

	Sentence Location	
	Position 1 Noun Phrase	Position 2 Verb+Prep
Long-reduced	570	898
Long-unreduced	558	735
Short-reduced	568	622
Short-unreduced	597	591

Table 1. Mean 2-word by 2-word reading times (in msec).

interacted with reduction ($p < .02$). Subsequent analyses will focus on the preposition length x reduction interaction at each sentence position.

At position 1, the noun phrase, there were no effects for preposition length, reduction, nor the interaction, all $ps > .25$. No effect is expected since the relative clause or preposition had not been encountered. At position 2, we see the effect of the preposition manipulation and reduction, because the verb and preposition are presented together. Reading speeds are slower for reduced sentences than for unreduced sentences, $F(1,30) = 4.74, p < .04$, and the segments with the longer prepositions took longer to read

than did the segments with the shorter prepositions, $F(1,30) = 23.67$, $p < .001$. There is a marginal interaction between reduction and preposition length, $F(1,30) = 3.06$, $p < .09$. Evidence for a gardenpath is seen when the ambiguous (reduced) condition is slower than the unambiguous (unreduced) condition. Such an effect is present only in the sentences with long prepositions where reading times in the reduced condition are longer (898 ms) and in the unreduced condition (735 ms), $F(1,30) = 6.12$, $p < .02$. This effect is not present in the sentences with the short prepositions, $F(1,30) = 2.77$, $p > .10$.

Discussion

The results of this experiment suggest a model of parsing that involves a variety of constraints in order to account for the resolution of syntactic ambiguity and explain the conditions that will result in the gardenpath effect. We replicated our earlier result, in experiment 1, demonstrating that with sufficiently constraining past-participle biased noun phrases the gardenpath can be avoided. However, in the present experiment, when the same sentences were modified with a longer preposition, the gardenpath returned.

General Discussion

Such results are inconsistent with a parser that adopts a single parsing preference (such as Minimal Attachment). Consistent with the present set of results is a syntactic decision mechanism that can take into account the characteristics of the verb form, semantic or thematic information, and the disambiguating cue of the preposition (see Burgess & Lund, 1994). However, the value of the disambiguating preposition is not absolute. In order for the gardenpath to be avoided, it seems important that the preposition be integrated with the ambiguous verb. A longer preposition, which takes longer to read, will delay this integration process and result in a gardenpath. It is likely that prepositions serve to disambiguate along various dimensions of information. For example, the preposition, *by*, can be used to denote a location, rather than used in the agentive, such as described in this experiment. Nor is the constraint of the semantic bias of the NP absolutely constraining. The context effects observed in this paper were a function of the strength of the semantic bias and this interacted with the availability of the disambiguating preposition. This pattern of results takes us one step further in specifying the variety of constraints that can operate on syntactic decisions and the conditions in which they will occur (Burgess & Lund, 1994; Burgess & Tanenhaus, 1992; MacDonald, 1994; Trueswell, Tanenhaus, & Garnsey, 1992).

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