

Lexical Projection and the Interaction of Syntax and Semantics in Parsing

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A series of self-paced reading studies utilized an embedded anomaly technique to investigate long-distance dependencies with dative verbs. Previous research in our lab demonstrated that argument structure influences the gap-filling process. Experiment 1 extended that work by demonstrating that dative verbs pattern with other complex transitive verbs (i.e., a fronted filler that is implausible as the direct object will not be interpreted as the direct object until the absence of a noun phrase after the verb forces the postulation of a direct object gap. This pattern contrasts with that of transitive verbs that subcategorize for a single internal argument position, where fronted fillers are obligatorily interpreted as the direct object). Experiments 2 and 3 investigate the prediction that semantic analyses precede syntactic analyses in dative questions. It is argued that the lexical information about argument structure and thematic roles can guide semantic interpretation.

A year ago we published a progress report on a project investigating the use of lexical information in parsing sentences with long distance dependencies (Tanenhaus, Boland, Garnsey, & Carlson, 1989). These studies used an anomaly detection task in which subjects read sentences one word at a time, pacing themselves with button presses and terminating the trial if a sentence stopped making sense. We demonstrated that

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gaps are posited and filled immediately at verbs that are typically used transitively. That is, sentences such as *Which food did the boy read in class?* were judged to stop making sense at the verb, *read*, indicating that subjects had posited a gap at *read* and interpreted *which book* as its filler. These results are consistent with a growing body of evidence from a variety of experimental paradigms showing that gaps are filled as soon as a verb is encountered. The evidence includes “filled-gap” studies (Crain & Fodor, 1985; Stowe, 1986; Tanenhaus et al., 1989; Clifton & Frazier, 1989), cross-modal priming studies showing priming to the antecedent of a trace beginning at the verb (e.g., Clifton & Frazier, 1988; Nicol & Swinney, 1989; Swinney, Ford, Frauenfelder & Bresnan, 1988), anomaly effects beginning at the verb with evoked potential and behavioral response measures (Garnsey, Tanenhaus, & Chapman, 1989; Tanenhaus, Stowe, & Carlson, 1985; Tanenhaus et al., 1989), and assorted reading time measures (Clifton, Frazier, & Connine, 1984; Clifton & Frazier, 1989).

Along with these early-filling results, we also reported what looked at first like an exception. We did not find implausibility effects at the verb in sentences where the verb subcategorized for an infinitive complement as well as a direct object (e.g., *remind*, in sentences such as *Which movie did your brother remind to watch the show?* This suggested that implausible fillers were not immediately assigned to the potential direct object gap. In order to determine whether or not there was a real delay in gap-filling after these types of verbs, we conducted an additional experiment to test whether gaps were posited for plausible fillers. Using sentences like *Which child did your brother remind them to watch?* we found increased reading times and more “doesn’t make sense” responses after the pronoun, *them*, in sentences with plausible fillers compared with both declarative controls and sentences with implausible fillers. This suggests that gaps are posited and filled at “infinitive complement verbs” if the filler is plausible, just as gaps are always posited and filled at “simple transitive” verbs. We have proposed that the reason that gaps are not posited at infinitive complement verbs if the filler is not plausible is related to the complexity of the verb argument structure. Our proposal was that recognition of the verb makes available the set of arguments/thematic roles associated with the verb, and these roles are identified as potential gap sites to the parser. Since the infinitive complement verbs had a role (or set of roles) associated with the infinitive complement, as well as a role associated with the direct object, when a filler was implausible as the direct object it was assumed to be a filler for a later argument position. One consequence of this view is that gap-filling takes

place immediately at the verb using thematic (or conceptual) representations prior to direct syntactic evidence marking the syntactic position of the gap.

This paper discusses experiments designed to further explore the use of argument structure in the gap-filling process. The first experiment replicates the difference between simple transitive and infinitive complement verbs, which we briefly described above, and includes a new verb type (datives), which we predicted would pattern with the infinitive complement verbs. The second and third experiments more directly test the hypothesis that filler-gap interpretation takes place prior to the parser’s having encountered the syntactic gap position.

EXPERIMENT 1

Our purpose was, first, to replicate the difference we found between simple transitive and infinitive complement verbs in a previous experiment (Tanenhaus et al., 1989). Second, we wished to further test our hypothesis by looking at another verb type that has more than one internal argument. If, as we believe, simple transitive verbs oblige the parser to posit and fill a direct object gap because there are no other argument positions that the filler could fit into, then dative verbs should not induce the parser to posit and fill the direct object gap since there is another argument position available. The datives should pattern like the infinitive complement verbs.

We selected 12 verbs of each type for use in the experiment. Many of the verbs had several alternative argument structures, but none of the simpler verbs had one of the more complex structures as a possibility. Although both infinitive complement verbs and dative verbs can be used with only a single internal argument (e.g., *Tom told Bill* and *John sent his assistant*), we chose verbs where the role associated with the second internal argument seems to be a necessary part of the event described by the verb, even if it is not made explicit in the sentence. An informal test for this is that, without context, a sentence using the subcategorization with two internal arguments seems intuitively more natural than one using the subcategorization with only one internal argument.

A sentence set, consisting of two sentences that were identical except for the fronted *wh*-phrase, was constructed for each verb. In all cases, the *wh*-phrase was the filler for a gap in the direct object position. In one version the filler was plausible as the direct object and in the other

Table I

Condition		Critical word positions					
		N	V	V+1 ^a	V+2 ^a	V+3 ^a	V+4 ^a
Trans-Plaus	Which star did the	assistant	watch	all	through	the	night
Trans-Implaus	Which stone did the						
Dative-Plaus	Which poem did the	babysitter	read	in	a	funny	voice
Dative-Implaus	Which baby did the						
Icomp-Plaus	Which girl did the	woman	remind	to	watch	the	show
Icomp-Implaus	Which movie did the						

^aThe final four words in a sentence formed either an adverbial phrase (for the first two verb types) or an infinitive complement (for the Icomp verb type).

version the filler was implausible. The implausible fillers were always plausible as the indirect object. Sample sentences are shown in Table I. At the verb, there was no syntactic or semantic evidence to force a filler-gap assignment. That is, it was always possible to complete the sentence in such a way that the *wh*-phrase would be a plausible filler for some later gap-position (e.g., *Which stone did the assistant watch the craftsman carve ____?*). Plausibility effects at the matrix verb are evidence that the filler was immediately associated with the (then) potential gap position. Plausibility effects a word or two later indicate that the filler-gap association was not made until it became clear that there was indeed a gap in that position which needed a filler.

Thirty-six University of Rochester undergraduates served as subjects. All were native speakers of English. The experimental procedure was the same for all three experiments. Sentences accumulated across an IBM PC monitor. Subjects controlled the word-by-word presentation rate by pressing a key. Subjects were instructed to continue pressing the key for each new word as long as the sentence continued to make sense. If the sentence stopped making sense, they were to press a different key as soon as they noticed the implausibility. This was called a "no" response. After a "no" response, presentation of the sentence was halted and a new trial began. Subjects were told to read rapidly and carefully. Reading times were collected from the onset of each word. Thus, we had two measures of implausibility: increased reading times, and an increased number of "no" responses at a particular word position.

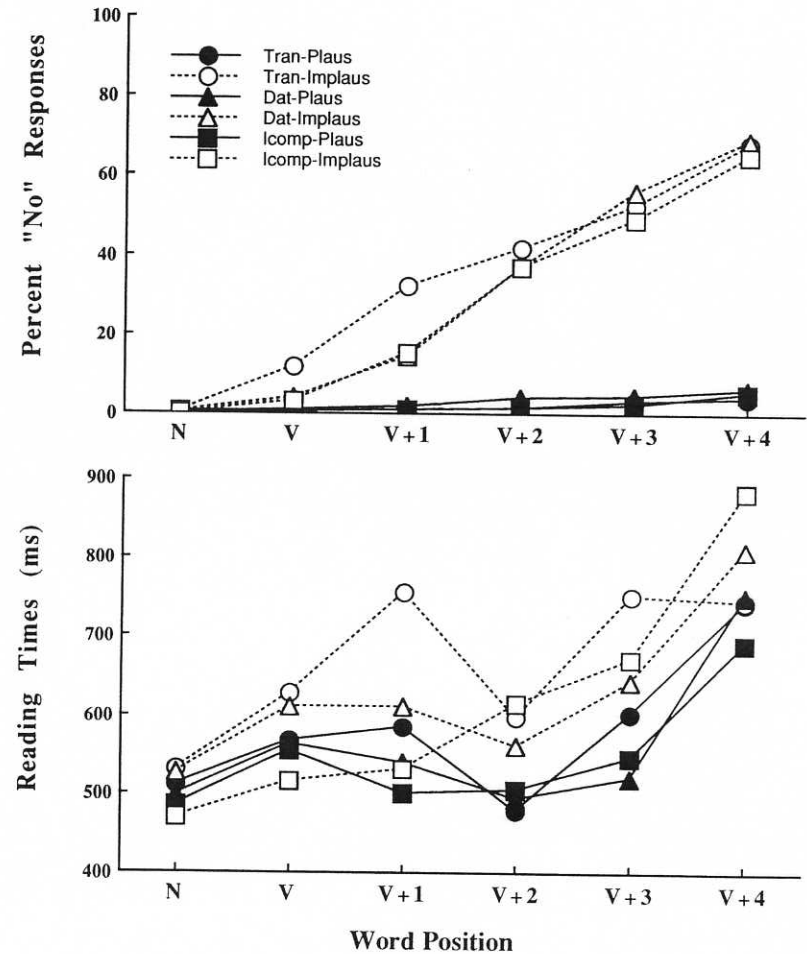


Fig. 1. The upper half of the figure displays the cumulative percent of the trials on which a "no" response was given, and the lower half displays mean reading times for those sentences judged to make sense. Both are presented by condition at each critical word position.

Results

A summary of the results can be seen in Figure 1. Replicating our previous experiments, there were markedly different patterns between sentences with simple transitive verbs and those with infinitive complement verbs. Simple transitive sentences showed increased numbers of

“no” responses and slower reading times for the implausible versions, beginning at the verb. Infinitive complement sentences showed no effects until one word later. As predicted, dative sentences patterned with the infinitive complement sentences. The top half of the figure shows the cumulative percentages of “no” responses. Subjects began responding “no” to the simple transitive sentences at the verb. They began responding “no” to the infinitive complement and dative sentences one word later. In order to decrease the dependence between correlated variables, the analysis⁴ was done on the proportion of “no” responses out of the remaining possible responses at each position. There were main effects of plausibility and word position, and overall interactions of plausibility by word position, and verb type by plausibility by word position (marginal). There was a significant effect of plausibility at the verb (V) for the transitive sentences, but not the dative or infinitive complement sentences. At all of the postverbal word positions there were plausibility effects for all verb types.

The lower half of the figure shows the mean reading times for positive responses only (while subjects thought the sentences made sense). There were main effects of plausibility, word position, and verb type (marginal). There were marginal plausibility effects at the following word positions/verb types: transitives, V and V + 2; datives, V + 1.

Discussion

The results support the hypothesis that argument structure is used for filler-gap assignment. Plausibility effects were seen at the simple transitive verbs but not at the dative or infinitive complement verbs. Plausibility effects for these verbs were seen only after syntactic information made it clear that the filler was the direct object of the verb. The effects can be seen most clearly in the % No data, but they are reflected in the reading time trends as well. These results suggest that even complex lexical information is available early in the comprehension process and can influence structure assignment. Presumably, recognition of a verb makes available the set of roles associated with the subcategorized arguments of the verb. An “active filler” (Clifton & Frazier, 1988) is immediately associated with one of these roles, with preference given to

⁴A 2(list) × 3(verb type) × 2(plausibility) × 6(word position) ANOVA was performed on both subject and item means. The effects we discuss were significant at $p < .05$ in both the subject and item analysis. Identical ANOVAs were performed on the reading time data.

the role associated with the direct internal argument as long as the filler is plausible in that role.⁵

According to our hypothesis, a filler (in an IO question) that is semantically inappropriate for the direct object role but is appropriate for the indirect object role should be immediately assigned the IO role. We tested this by constructing IO question pairs with fillers that were not plausible direct objects but were plausible indirect objects. One filler in each pair became semantically implausible when the direct object was encountered. Consider sentences (1) and (2).

(1) Bob wondered which bachelor Ann granted a maternity leave to (t) this afternoon.

(2) Bob wondered which secretary Ann granted a maternity leave to (t) this afternoon.

It doesn't make sense to grant a maternity leave to a bachelor, although you can grant bachelors other things. Note that *bachelor* cannot fill the direct object role and also note that *maternity leave* can be a plausible direct object of *grant*, as is illustrated in (2). The question of interest is: When do people notice the anomaly—before or after *to*, which marks the position of the trace?

EXPERIMENTS 2 AND 3

Experiment 2

We compared sentences like (1) and (2) using the same procedure used in Experiment 1. In all cases, the filler was implausible as a direct object but plausible as an indirect object, and the verbs were alternating datives. This experiment manipulated filler plausibility given a particular direct object (e.g., it makes sense to grant *something* to a bachelor, but not a *maternity leave*).

A summary of the results thus far (22 subjects) can be seen in Figure 2. Subjects pressed “no” significantly more often in sentences with implausible fillers beginning at the direct object noun phrase (*maternity*), before the *to*. The reading time data have a baseline problem that partially

⁵This proposal is similar to Pritchett (1988), but unlike Pritchett, we would argue that reference is made to the content of the roles.

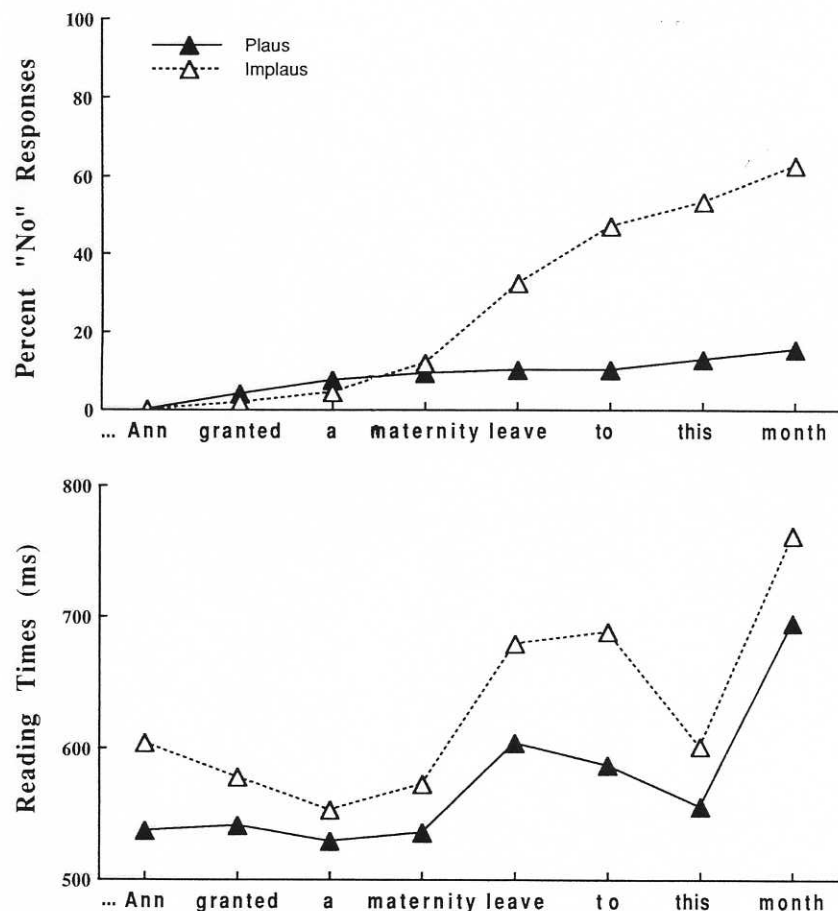


Fig. 2. The upper half of the figure displays the cumulative percent of the trials on which a "no" response was given, and the lower half displays mean reading times for those sentences judged to make sense. Both are presented by condition at each critical word position.

obscures our plausibility effect. However, if you subtract the baseline difference, the reading times for the implausible sentences get slower beginning at *leave*, one word later than the effect in the % "no" responses. This difference reaches significance at *to*.

These results suggest that the filler is treated as the indirect object by the end of the NP (before the syntactic trace that marks the gap position). However, this result alone does not constitute evidence that gap-filling is

conceptual rather than syntactic. The verbs we used were alternating datives, which have two possible structures:

- (3) Which secretary did Ann grant (t) the maternity leave?
 (4) Which secretary did Ann grant the maternity leave to (t)?

As soon as they read the verb, subjects may posit a trace immediately after the verb, resulting in the structure in (3). However, there is reason to doubt that traces associated with indirect object roles are posited after dative alternation verbs. It has often been observed that many speakers find IO questions with medial gaps, such as (3), to be only marginally acceptable. (See Fodor, 1978; Langendoen, Kalish-Landon & Dore, 1974, for discussion and reviews.) In fact, there are a number of processing-based explanations that assume that these sentences are difficult because the parser fails to posit a trace following the verb.

For example, J. D. Fodor (1978) proposed that when a filler has been identified, the parser posits a gap (trace) after a verb that is typically used transitively after first trying the next constituent to make sure that the possible gap position isn't already taken by an overt NP. For IO dative questions such as (3), the parser will miss the trace because the constituent immediately following the verb is an NP. While the "Try the Next Constituent" strategy provides an elegant account for why sentence (3) is only marginally acceptable, whereas sentence (4), with a clearly marked trace, is fine, it is clearly incompatible with the previously mentioned evidence for immediate gap-filling.

This leaves us with something of a paradox. If people may posit a trace immediately after the verb, we lose an explanation for the awkwardness of IO questions without *to*'s. If people can't posit a trace until after reading the *to*, then it is difficult to account for the early plausibility effects we found in Experiment 2. There may be a way out of the paradox. Perhaps people propose a trace after an anticipated, but not yet encountered, *to*. That is, people expect a *to* (and a trace), but they interpret the filler semantically before they get syntactic evidence for the trace. Experiment 3 was designed to test this hypothesis.

Experiment 3

We used the plausible sentences from Experiment 2 to construct IO questions with and without *to*'s. Example sentences are presented in (5) and (6):

