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THEMATIC RELATIONS IN PARSING

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1. Introduction

A basic task in sentence comprehension involves the identification of constituents and the grammatical functions they serve. This task is interestingly complicated by the existence of lexically empty categories, or gaps, as in (1):

(1a) I_i want e_i to laugh.

(1b) Who_i do you want e_i to laugh?

Viewed strictly in terms of the local characteristics of an input string, a gap is a gap; it is a position which must (or may) contain a phrase, but fails to contain a lexically specified element. However, sharply distinct types of lexically null elements exist, and have been the focus of a great deal of recent linguistic investigation (Chomsky, 1982). The proper interpretation of a sentence containing a gap thus requires the parser to identify its type correctly, using available linguistic information. The gap, for example, may be a null pronominal (PRO), as in (1a), above, or it may be the trace of a questioned element, as in (1b). Empty categories thus may be characterized as superficially ambiguous items, and it is the task of the sentence parsing mechanism (the "parser") to resolve the ambiguity.

The linguistic type of a null element must be identified, and the phrase that controls its interpretation (its filler) must be determined. Different categories of linguistic information are relevant for determining the analysis of different types of gaps. If the parser quickly identifies the type of an empty element, it might be able to use different categories of information in the initial interpretation of different types of gaps. For instance, the processing of null pronominals (as in (1a)) might be similar to the processing of overt pronouns in terms of the information used to guide parsing, but different from the processing of traces of moved elements (as in (1b)). Identifying the principles underlying the parser's early classification and interpretation of gaps could thus help illuminate the structure of the human sentence parsing mechanism, and the relations among the various subsystems implicated in language comprehension.

The initial psycholinguistic studies of sentences with gaps and fillers indicated that the parser initially assigns the most recent potential filler to each gap encountered (Wanner & Maratsos, 1978; Fodor, 1978). Experimental tests of this "Most Recent Filler Strategy" have confirmed the existence of a recent filler preference in ambiguous and temporarily ambiguous sentences, as illustrated by the preference for (3a) over (3b), below, as a continuation of the fragment in (3). Interesting questions have been raised about whether this strategy applies only in cases of true ambiguity (Crain & Fodor, in press), or also in cases where various types of apparently available linguistic information should block its application (Frazier, Clifton, & Randall, 1983). Proponents of the latter position have argued that the pervasive applicability of the Recent Filler Strategy permits interesting conclusions about the organization of the parser. However, for present purposes, we can overlook these questions concentrate upon cases of true temporary ambiguity.

The Recent Filler Strategy is of interest because it provides a means of testing whether the human sentence processing mechanism (henceforth, "the parser") initially treats all empty categories on par¹, or whether certain empty categories are treated in a distinct manner even in the very earliest stages of syntactic analysis. If all empty categories are treated alike, then sentences conforming to the recent filler strategy should be easier to process than their "distant filler" counterparts, regardless of the true status of the empty category, i.e., regardless of whether a gap is in fact a wh-trace, as in (2a), an obligatorily controlled PRO, as in (2b), or a thematically controlled PRO, as in (2c)².

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- (2a) Who_i did Jeremy see t_i?
 (2b) Jill_i promised PRO_i to laugh.
 (2c) Jessica_i gave Sam War and Peace PRO_i to read.

Several considerations suggest that thematically controlled PRO and other types of pragmatically controlled PRO (see note 3) may be classified differently than trace and obligatorily controlled PRO in initial parsing. Obligatorily controlled PRO and wh-trace can be confused with each other in the left-to-right parsing of a sentence, as in (3), where the gap following want may turn out to be wh-trace, as in (3b), or obligatorily-controlled PRO, as in (3c). By contrast, pragmatically-controlled PRO is not confusable with a wh-trace, as indicated by the ungrammaticality of (4).

- (3a) Who did Jenny want to talk...
 (3b) Who_i did Jenny want t_i to talk at the meeting? (Distant filler)
 (3c) Who_i did Jenny_j want PRO_j to talk to t_i at the meeting? (Recent filler)
 (4) *Who_i did Jessica buy (t) some books PRO_i to please Mary?

Further, wh-trace and obligatorily controlled PRO seem to require fillers that c-command the gap, while the controller for pragmatically controlled PRO need not c-command the gap, as in the null (PRO) subject of the purpose clause sentence in (5a), where Mary does not c-command PRO.

- (5a) Jacob lent some books to Mary_i PRO_i to read on vacation.
 (5b) Jacob_i borrowed some books from Mary PRO_i to read on vacation.

Finally, the thematic structure of the matrix verb is important in determining the appropriate assignment of a controlled for the PRO in sentences like (5), as argued by Nishigauchi (1983)³. A hierarchy of thematic relations specifies that with verbs taking Goal, Source, and Theme arguments (as in (5)), the Goal is ranked higher than the Source, which in turn is ranked higher than the Theme. Regardless of which grammatical function the Goal assumes, the Goal will typically control the interpretation of the PRO subject in purpose clauses like those in (5).

To determine whether the initial filler assigned to pragmatically-controlled PRO is influenced by the linear order of potential fillers or by the thematic structure of the matrix verb, we designed a grammaticality judgment experiment to test the comprehension of sentences like those in (5). If all empty categories are treated alike in initial parsing, we would expect sentences like (5a), where the most recent NP does in fact control

the interpretation of the PRO subject, to be comprehended more quickly than those in (5b), where the recent NP is not the correct filler. However, evidence suggesting that the relative order of the true controller with respect to other NPs does not influence comprehension time would argue that pragmatically controlled PRO is processed differently from other gaps, presumably because pragmatically controlled gaps are identified as +pronominal when they are initially postulated. To anticipate the results of the first experiment, we did find that pragmatically controlled PRO was processed differently than wh-trace and obligatorily controlled PRO, being sensitive to the thematic structure of the matrix verb and to the thematic roles played by the NPs. Before presenting the details of the experiment, we wish briefly to discuss the potential roles of thematic relations in language comprehension.

Linguistic theory offers a very detailed account of the specialized vocabulary systems needed to represent the grammar of a language. It is clear that, by and large, this vocabulary (e.g., distinctive features in phonology, +Noun and +Verb in syntax) does not coincide with the vocabulary needed for representing real world knowledge. There is, however, one plausible exception. The vocabulary of thematic relations (e.g., Agent, Goal, Source) does play a role in syntactic theory (Chomsky, 1982, for example). It may well play a role in the cognitive organization of real world knowledge as well (Jackendoff, 1983). If so, then thematic relations are an obvious candidate for a vocabulary that is shared by the linguistic and nonlinguistic systems, and as such might serve as an interface between the grammatical and the nongrammatical components of language processing. Thus, independent of questions concerning the classification of empty categories in parsing, the role of thematic relations in parsing deserves more attention than it has received to date. An understanding of how thematic relations influence parsing is likely to be central to an account of how real world knowledge and linguistic knowledge is integrated in the comprehension of language (see Rayner, Carlson, & Frazier, 1983, for an hypothesis and preliminary evidence about the mechanisms permitting coordinated use of these distinct knowledge sources in a modular theory of sentence processing).

The purpose clause sentences in (5) offer one way to explore the role of thematic relations, since thematic relations are crucial in determining the ultimately appropriate controller for the empty PRO subject in a purpose clause. Sentences with rationale clauses, e.g., (6), provide another means, since the pragmatically controlled empty (PRO) subject in these clauses is typically controlled by the Agent of the matrix verb (as indicated by the interpretation of (7), where the Agent must control the PRO subject, even though the Agent is not overtly expressed).

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- (6a) John_i lent some books to Mary PRO_i to keep Billy from destroying them.
- (6b) John_i borrowed some books from Mary PRO_i to keep Billy from destroying them.
- (7) The Mercedes was bought PRO to impress Mary.

Thus, we included rationale clauses, as well as purpose clauses, in the experiment.⁴

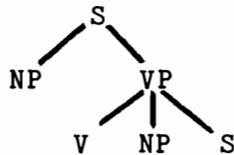
In the first experiment, we tested the hypothesis that thematic relations, not recency, govern the initial interpretation of the null (PRO) subjects of purpose clauses such as (5) and rationale clauses such as (6). To further explore the role of thematic relations, we conducted a second experiment in which we replaced null subjects with overt pronouns.

2. Experiment 1.

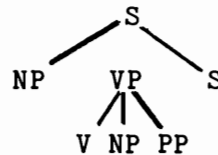
Experiment 1 was designed to determine whether processing of the empty subjects of purpose and rationale clauses is influenced by recency or only by the thematic structure of the matrix verb. To address this question, we constructed 12 quadruples of sentences like those illustrated in (5) and (6) (and repeated, with mnemonic names, as I and II in Table 1). We also included 6 pairs of sentences like those in (8) and 6 pairs like those in (9) (III and IV in Table 1). These sentences were included simply to confirm our assumptions about the structure of the adjunct clauses. Our earlier work on parsing strategies (e.g., Frazier, 1979; Frazier & Rayner, 1982) leads us to expect that clauses with ambiguous structural attachments will be minimally attached into the current phrase marker as a sister to recently encountered items. The minimal nodes principle predicts a preference for a complement clause analysis in cases of ambiguity, as can be seen by examining the structures in (10). Hence, we expect the complement clauses in (8a) and (9a) to be comprehended faster than their (b) counterparts. Further, purpose clauses (8b) should be preferred to rationale clauses (9b) due to the preference for low attachment (i.e., for new items to be analyzed as a sister to recent items).

- (8a) The principal chose an older student_i PRO_i to go to the conference.
 (8b) The principal_i chose an older student_j PRO_i to take t_j to the conference.
 (9a) Billy programmed the computer_i PRO_i to do all his homework.
 (9b) Billy_i programmed the computer PRO_i to escape doing his homework.

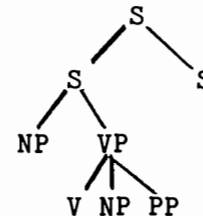
(10a) Complement
Clause



(10b) Purpose
Clause



(10c) Rationale
Clause



2.1 Methods

Illustrations of the four contrasting pairs of sentence forms appear in Table 1. These critical sentence forms will be referred to as PC-OBJ (purpose clauses whose verbs take Goal, Source, and Theme arguments, and whose Goal appears in object position; Table 1, Ia) and PC-SUBJ (purpose clauses whose Goal appears in subject position; Ib). Twelve pairs of such sentences were constructed. Twelve pairs of R-1 (rationale clause sentences with the verbs of PC-OBJ; IIa) and R-2 (rationale clause sentences with the verbs of PC-SUBJ; IIb) sentences were also constructed, matched one to one with the PC-OBJ and PC-SUBJ sentences. The controls designed to demonstrate the preference for the complement analysis (due to the operation of Minimal Attachment and the Most Recent Filler strategy) over purpose clauses and rationale clauses are COMP-1 (complement sentences; IIIa); PC-COMP (purpose clauses with the same verbs as COMP-1; IIIb); COMP-2 (complement sentences; IVa); and R-COMP (rationale clause sentences matched in verb with COMP-2; IVb). Six sentences of each of these kinds were constructed. All sentences appear in Appendix A.

One hundred and thirty two University of Massachusetts undergraduates were tested. Each subject read one version of each of the 24 sentences just described, embedded in a list of 147 sentences and nonsentences of various forms. The study was conducted as two separate experiments, the first testing 60 subjects and the second, 72. The two experiments were identical,

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except that an equipment design error which resulted in reaction times being computed from the release, not the depression, of the pushbuttons in Experiment 1 was corrected in the second experiment.

After receiving instructions about what made a sentence unacceptable (simple grammatical errors such as verb-number disagreement, missing or extra verb arguments, anomalies, etc.) and taking a brief pretest of their concept of ungrammaticality, subjects received six practice sentences and then the 147 items (85 sentences, 62 nonsentences) of the experiment. On each trial, a randomly selected sentence or nonsentence was presented in a word by word fashion, centered on a video screen, with each word presented for 300 msec and followed by a 50 msec blank period. Subjects were instructed to press one button with their left hand as soon as they decided that an item was unacceptable, and another button with their right hand as soon as they decided that a sentence was acceptable. They received no feedback, except that if they failed to respond by 2000 msec after the end of a sentence or the point of unambiguous ungrammaticality (8000 msec in the case of one set of complicated nonsentences that violated island constraints) a tone sounded and the trial was terminated.

Each subject made judgments about three instances of each of the forms of sentences illustrated in Table 1. Their reaction times and the responses they made were recorded. Counterbalancing procedures were used to ensure that each sentence was tested equally often in each form.

2.2 Results

The mean reaction times of correct responses (after eliminating all trials on which the 2000 msec deadline elapsed, and averaging over experiments) and the proportions of correct "acceptable" judgments appear in Table 1. Examination of Conditions III and IV, which contrast S-complement sentences with purpose clause and rationale clause sentences respectively, establishes a clear preference for the complement constructions, confirming our assumptions about the preferred attachment of these clauses.

Table 1

Acceptability Judgment Reaction Times and Proportion
"Acceptable" Judgments, Experiment 1

Condition	Illustrative Sentence (repeated from the text)	RT	Prop Corr
PC-OBJ	Ia. John lent some books to Mary to read on vacation.	1012	.89
PC-SUBJ	Ib. John borrowed some books from Mary to read on vacation.	980	.88
R-1	IIa. John lent some books to Mary to keep Billy from destroying them.	966	.84
R-2	IIb. John borrowed some books from Mary to keep Billy from destroying them.	1025	.88
COMP-1	IIIa. The principal chose a student to go to the conference.	987	.96
PC-COMP	IIIb. The principal chose a student to take to the conference.	1042	.78
COMP-2	IVa. Billy programmed the computer to do all his homework.	1054	.85
R-COMP	IVb. Billy programmed the computer to escape doing his homework.	1077	.76

Comprehension responses were significantly faster and more accurate for sentences with sentential complements than for corresponding purpose clauses or rationale clauses (compare the COMP-1 and -2 sentences with the PC-COMP and R-COMP sentences; RT: $F_1(1,130) = 6.46$, $p < .02$; $F_2(1,22) = 5.38$, $p < .04$; proportion correct: $F_1(1,130) = 52.08$, $p < .001$; $F_2(1,22) = 13.29$, $p < .01$).⁵

The effect was significantly smaller for the rationale sentences than the purpose clause sentences in the subjects analysis, but not in the sentences analysis. Thus, we can conclude that our subjects preferentially analyzed an ambiguous clause as a complement clause when this analysis was permitted by the materials.

We can ask whether the Recent Filler Strategy applies in the interpretation of unambiguous purpose clause sentences, for which thematic information is of clear relevance. The answer is, it does not. In fact, RT to (Ia), whose PRO is controlled by the most recent possible antecedent, was slower than RT to (Ib), whose PRO is controlled by a distant antecedent (although the level of significance was marginal; $p = .10$). This deviation from the Most Recent Filler strategy was assessed statistically by performing analyses of variance on the I and III sentences of Table 1. The factors in the analysis were (a) whether the sentences contained unambiguous purpose clauses or permitted a temporary analysis as a complement clause (I vs. III), and (b) whether the matrix subject or the matrix object was the proper antecedent of PRO (the a forms vs. the b forms). In both the analysis of reaction time and the analysis of proportion correct responses, the two factors interacted significantly (RT: $F_1(1,130) = 10.62$, $p < .001$; $F_2(1,32) = 7.43$, $p < .01$; proportion correct: $F_1(1,130) = 31.04$, $p < .001$; $F_2(1,32) = 15.07$, $p < .001$). As reported already, responses were faster and more accurate to COMP-1 than to PC-COMP, consistent with the attachment preferences predicted for these sentences. However, the opposite pattern held for the unambiguous purpose clause sentences. It appears that, when a sentence has a clearly nonobligatorily controlled PRO in a purpose clause configuration, the Most Recent Filler strategy does not apply.

One final analysis contrasted the PC-OBJ and PC-SUBJ sentences with the R-1 and R-2 sentences, which shared the same verbs, as a control for superficial and (from our standpoint) irrelevant differences between the purpose clause sentences. The interaction of the factors of sentence form (purpose clause vs. rationale clause) and verb (lend-type vs borrow-type; thus, object vs. subject controller for the purpose clause sentences) was significant or nearly so in the RT analysis, $F_1(1,130) = 8.05$, $p < .01$; $F_2(1,22) = 3.76$, $p < .07$). However, it did not approach significance in the proportion correct analysis. In this latter case, purpose clause sentences were responded to more accurately than rationale clause sentences, $F_1(1,130) = 15.44$, $p < .001$; $F_2(1,22) = 3.77$, $p < .07$). The reaction time data indicate that the difference between the thematically different versions of the purpose clause sentences, PC-OBJ and PC-SUBJ, was not due simply to superficial lexical differences, since the direction of the difference was reversed in the lexically-matched R sentences.

2.3 Discussion

The Most Recent Filler strategy, whose operation has been identified in sentences with a null subject that corresponds to a

wh-trace or an obligatorily controlled PRO (Frazier, Clifton, & Randall, 1983), was presumably used in the present experiment for sentences which required a S-complement analysis (sentence forms IIIa and IVa). However, it did not appear to be used for unambiguous purpose clause sentences (Ia and Ib). Had it applied here, it would have entailed that purpose clause sentences were understood faster when the Goal (the eventual controller of PRO) was in matrix object position than when it was in matrix subject position. The opposite occurred. Purpose clause sentences whose matrix verb (e.g., borrow) requires a Goal in subject position were understood at least as quickly as purpose clause sentences whose matrix verb (e.g., lend) has a Goal in an object position. Thus, our data demonstrate that the Most Recent Filler strategy for assigning antecedents to empty elements does not apply in the case of purpose clause sentences.

Although alternative interpretations are possible, the purpose clause results are consistent with the claim that thematic information is used in determining the initial interpretation of pragmatically controlled PRO. In the final interpretation of such sentences, the Goal is clearly taken to control the PRO. The absence of a statistically significant difference between the case where Goal was object (Ia) and the case where Goal was subject (Ib), combined with the demonstration of a significant preference for complement structures (whose final interpretation follows the Most Recent Filler principle) over structures with a pragmatically controlled PRO when complement structures were permitted, strongly suggests that the Goal was the first-chosen controller of PRO in both (Ia) and (Ib). If the marginally significant superiority of (Ib) over (Ia) is to be trusted, it can be attributed to the greater ease of retrieving or otherwise processing subjects (or topics), as contrasted with grammatical objects.

Further, the significant difference between rationale clause sentences with subject-Sources vs. subject-Goals (IIa vs IIb) argues that pragmatically controlled PRO is not initially interpreted by any purely structure-based strategy, independent of thematic information. In such a case, we would have expected no systematic difference between the subject-Source and subject-Goal sentences. Thus, in all respects, Experiment 1 suggests that recency is not important in the interpretation of pragmatically controlled PRO, but thematic relations are.⁶

3. Experiment 2

To investigate whether overt pronominals pattern like null pronominals, we conducted a second experiment using sentences with overt pronouns, whose interpretation (determined by pronoun gender) is either consistent, or inconsistent, with the hypothesized preferred interpretation. We obtained a measure of

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processing complexity immediately after a pronoun in subject position of a subordinate clause. It is acceptable for a pronoun in subject position of such clauses to be coreferential with either the subject or the object of the main clause. However, the thematic structure of the main verb may influence the initial processing of such pronouns, especially under circumstances where the semantic relation between the main and subordinate clauses is similar to the semantic relation between a main clause and a purpose or rationale clause. The clausal connective so seems (in some of its usages) to be semantically similar to a purpose clause in terms of its relation to the main clause. It can be used to convey similar information, and there is at least a strong preference for it to be interpreted with future reference, as purpose clauses seem to be. Compare (11a-d):

- (11a) Mary gave a book to Lynne to read on vacation.
- (11b) Mary borrowed a book from Lynne to read on vacation.
- (11c) Mary gave a book to Lynne so that she could read it on vacation.
- (11d) Mary borrowed a book from Lynne so that she could read it on vacation.

We constructed sentences which began like the fragments in (12a-d). If thematic relations determine the initial interpretation of pronouns (at least, in sentences presented in isolation) as they do for pragmatically controlled PRO, then readers should initially take Susan to control PRO in (12a) and (12b), while John would in (12c) and (12d). The gender of the pronoun is consistent with this preference in (12a) and (12c), but inconsistent in (12b) and (12d).

- (12a) John lent some money to Susan so she...
- (12b) John lent some money to Susan so he...
- (12c) John borrowed some money from Susan so he...
- (12d) John borrowed some money from Susan so she...

Finding slower comprehension for the inconsistent than for the consistent sentence forms would indicate that overt pronouns are treated like null pronominals during early stages of processing. Other patterns of results would argue against this view.

The semantic relation between a main clause and an rationale clause can be conveyed using the clausal connective because; cf. (13):

- (13a) Mary gave a stupid book to Lynne to annoy her.
- (13b) Mary gave a stupid book to Lynne because she wanted to annoy her.

Unlike so, because does not preferentially receive an

interpretation with future reference (note, John divorced Mary because/so she was sad). Thus, assuming that the interpretation of a because clause can be similar to that of a corresponding rationale clause, the b- and c- forms of (14) should be processed

- (14a) Lynne gave a present to Mark because he...
- (14b) Lynne gave a present to Mark because she...
- (14c) Lynne accepted a present from Mark because she...
- (14d) Lynne accepted a present from Mark because he...

more quickly than their counterparts, since in these forms the pronoun is coreferential with the Agent expressed in the main clause.

Testing the hypothesis that overt pronouns and pragmatically controlled PRO are processed similarly is of interest for two reasons. First, if we are to understand the principles governing the human parsing mechanism, we must determine what elements form a natural class from the perspective of the parser, and why.⁷ Second, linguists have often considered the possibility that natural languages (or speakers of natural languages) are influenced by a strategy of "Avoid Pronoun." If this strategy does indeed operate in natural languages, we might expect PRO to replace overt pronouns in precisely those constructions where the antecedent of an overt pronoun is highly predictable on either structural or thematic grounds. In other words, if the interpretation of a pronoun is predictable across tokens of the same syntactic structure, one may "avoid pronoun" systematically, eventually changing the input data available to the language learner. This sort of account of the null subjects in purpose clauses and rationale clauses is tempting, given the intuitions about ambiguous sentences like (11c) and (11d). (This account would need to assume the loss of a preposition or complementizer, e.g., for, which historically would have assigned case to these positions, permitting the occurrence of overt pronouns in the first place.) The attempt to explain the distribution of pragmatically controlled PRO on the basis of predictable pronoun interpretations together with "Avoid Pronoun" might be promising if the processing of overt pronouns is in fact similar to the processing of PRO.

3.1 Method

Four versions of each of eight sentences like those in (15), and four versions of an equal number of sentences like those in (16), were constructed.

- (15a) Lisa sold a car to Jay so he could drive to work.
- (15b) Lisa sold a car to Jay so she would have some cash.
- (15c) Lisa bought a car from Jay so she could drive to work.

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- (15d) Lisa bought a car from Jay so he would have some cash.
- (16a) John lent some books to Mary because she wanted to read them.
- (16b) John lent some books to Mary because he wanted her to read them.
- (16c) John borrowed some books from Mary because he wanted to read them.
- (16d) John borrowed some books from Mary because she wanted him to read them.

Two versions of each sentence contained a verb whose subject is a Source (e.g., sold), and two contained a verb whose subject is a Goal or Recipient (e.g., bought). Each sentence contained one female proper name and one male name in the main clause. The following so or because clause contained the pronoun he or she referring back to either the Source of the Goal of the main clause.

Forty-eight University of Massachusetts undergraduates were tested. Each saw one version of each of these sentences, presented one word at a time centered on a computer-controlled video display, 350 msec/word, embedded in 88 other sentences. Presentation of the sentence was interrupted 350 msec after the presentation of the pronoun by a secondary task, designed to measure local processing difficulty. The secondary task used was a lexical decision task, in which a word or nonword was presented, in capital letters and flanked by four asterisks and an underline character, e.g., ****_AMUSEMENT_****. The subject was to press one button if the item was a real word, and a different button if it was a nonword. For all the sentences relevant to the present question, the test probe was a real word and immediately followed the pronoun in the so or because clause, but in the experiment taken as a whole, 46% of test probes were nonwords, and the position of the test probe varied across sentences. Reaction time to the test probe and accuracy of response were recorded. After the response was made to the test probe, presentation of the sentence continued. Each sentence was followed by a statement whose truth (relative to the just-presented sentence) the subject had to verify.

3.2. Results

The primary measure of interest was the reaction time to the secondary (lexical decision) task. The mean reaction times, after replacing the 0.8% of all responses over 2000 msec or more than four standard deviations greater than the subject's mean with the cutoff value, appear in Table 2. Error rates in the lexical decision task averaged 12%, and did not vary significantly across conditions.

Table 2

Secondary Task (Lexical Decision) Reaction Times,
Experiment 2

Type of Matrix verb	Connective			
	"so"		"because"	
	Antecedent of Pronoun			
	Matrix Subject	Matrix Object of Preposition	Matrix Subject	Matrix Object of Preposition
Obj=Goal ("sell")	(Source) 813	(Goal) 801	(Source) 834	(Goal) 876
Subj=Goal ("buy")	(Goal) 791	(Source) 784	(Goal) 820	(Source) 848

--note. The thematic role of the actual antecedent of the pronoun is parenthesized.

An analysis of variance of the RTs indicated that responses to probes of sentences with "so" were marginally faster than responses to probes of sentences with "because" ($F_1(1,47) = 10.15$, $p < .01$, but $F_2(1,14) = 2.91$, $p = .10$). This apparent difference may simply reflect differences among the lexical items used as probes. An interaction among all three factors (type of verb, type of connective, and gender-determined antecedent of pronoun) would be required to justify the claim that overt pronouns are treated like pragmatically controlled PRO. Faster probe RTs would be expected for "so" sentences when the antecedent of the pronoun was the thematic Goal than when it was the thematic Source, while faster probe RTs would be expected for "because" sentences when the pronoun antecedent was the matrix subject than when it was the matrix object-of-preposition. However, this interaction was thoroughly nonsignificant ($F < 1$ in both analyses). The only apparent structure in the data was the tendency for probes of "so" sentences to be faster when the pronoun antecedent was the matrix object than when it was the matrix subject, while probes of

"because" sentences were faster when the pronoun antecedent was the matrix subject than when it was the matrix object of a preposition (but $F_1(1,47) = 1.64$, $p = .20$, and $F_2(1,14) = 2.46$, $p = .14$). Disregarding the nonsignificance of this interaction, separate analyses of variance were conducted on the "so" and on the "because" sentences. The analyses of the "so" sentences yielded no F greater than 1.0. The apparent superiority of probes of "because" sentences when the pronoun antecedent was the matrix subject, as compared to when it was the matrix object-of-preposition, did not reach acceptable levels of significance ($F_1(1,47) = 1.76$, $p = .19$, and $F_2(1,7) = 3.30$, $p = .11$).

4. Conclusions

We have suggested elsewhere (Frazier, Clifton, & Randall, 1983; Clifton, Frazier, & Connine, 1984) that phrase structure information and strict subcategorization information govern the postulation of gaps during sentence processing. The present research shows that coindexing of postulated gaps (specifically, pragmatically controlled PRO) with antecedents can, in some cases, use additional sources of information. Gaps whose control could be structurally determined are initially taken as unspecified empty elements; however, gaps which must be pragmatically or thematically controlled initially are taken as PRO. A heuristic of assigning the most recent potential filler to non-PRO empty elements governs the initial indexing of traces and obligatorily controlled null elements. However, thematic information, possibly together with pragmatic information about discourse and real world relations, governs the initial indexing of null items initially identified as PRO. Apparently, thematic relations govern initial assignments of "gaps" that have been identified as pronominals (Experiment 1), but not overt pronominals (Experiment 2). Further, independent research (Rayner, Carlson, & Frazier, 1983; Ferreira, 1984) suggests that thematic relations participate only in the evaluation of alternative, independently-constructed, representations in the analysis of nonpronominal elements. Thus, the rule of thematic relations in parsing appears to be dependent upon the class of elements being parsed.

Footnotes

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1. We think it likely that the parser does honor case theory in initial stages of syntactic processing and thus does distinguish empty categories occurring in case-marked positions from those occurring in case-less positions. If so, then the most recent potential filler for a case-marked gap is the most recent (unused) filler in A-bar position; the most recent potential filler for other gaps would be the most recent (unused) filler in either A or A-bar position.

2. Wh-traces are governed by structural conditions (of binding theory, bounding theory; see Chomsky, 1982). By contrast, obligatorily-controlled PRO requires a filler which is essentially determined by the lexical properties of the higher verb. Compare: "John promised Mary PRO to leave," vs. "John forced Mary PRO to leave." The interpretation of thematically-controlled (or, more generally, pragmatically-controlled) PRO is apparently more free than the interpretation of other empty elements (consider the arbitrary interpretation in "To dance is fun"), though the restrictions on its interpretation are still being worked out (Bach, 1982; Faraci, 1974; Jones, 1984). It does seem relatively clear, however, that thematic relations and pragmatic plausibility considerations are often responsible for the appropriate interpretation of nonobligatory (pragmatically controlled) PRO. Typically a unique interpretation is not dictated by general structural conditions (as in wh-trace) or by the presence of a particular lexical item (as with obligatory control).

3. Nishigauchi (1984) argues convincingly that thematic relations are important in interpreting at least a subset of pragmatically controlled PROs. He proposes a thematic hierarchy to capture this observation, and draws a sharp distinction between thematic and pragmatic control. We will assume that Nishigauchi's thematic hierarchy for the interpretation of PRO in purpose clauses derives from the semantic requirement of purpose clauses, roughly, that the null subject correspond to the physical possessor of the theme of the matrix clause.

4. Notice that the sentences in (6) also provide a control for any complexity differences between verbs like lend (with Source-subjects) and verbs like borrow (with Goal-Subjects) that contribute to comprehension differences among purpose clause sentences, independent of their interaction with the PRO subject.

5. While the first run of this experiment yielded significantly slower RTs than the second run, no interactions of consequence involving the runs factor were detected. The factor will therefore be disregarded.

6. We must still explain the superiority of (IIa) over (IIb). One account claims that when a nonobligatorily controlled PRO is identified, as in (II) (or I), the sentence containing it is initially analyzed as structure (10b). Since such a structure requires a purpose clause interpretation, the Goal of the matrix sentence will be chosen as antecedent of PRO. In (IIb), this (ultimately erroneous) analysis receives some semantic or pragmatic confirmation before disambiguating syntactic information arrives. The confirmation occurs because the argument that fills the thematic role of Goal in sentences like (IIb) must have the semantic and pragmatic properties to be the subject of the adjunct clause. The matrix Agent must have such properties in rationale clause sentences, and the matrix Goal and Agent are the same argument in (IIb). In sentences like (IIa), on the other hand, the Goal may not always have the appropriate properties to be taken as subject of the adjunct clause, resulting in less likelihood of spurious confirmation of an analysis that must ultimately be changed, and thus, faster comprehension.

A different interpretation of the inferiority of (IIb) to (IIa) is that some verbs - more "borrow"-type than "lend"-type verbs - subcategorize for purpose clauses as optional complements, and that readers initially assign the purpose-clause syntactic structure to sentences with such verbs. Such initial misanalysis would require time-consuming reanalysis, accounting for the inferiority of the rationale clause sentences in question. However assuming that there are consistent differences among the verbs in the extent to which they invite the purpose clause analysis, this claim would also seem to predict that verbs which resulted in particular difficulty of comprehension of rationale sentences would yield particularly easy-to-understand purpose clause sentences. Thus, there should be a negative correlation, verb by verb, between the time taken to read a purpose clause sentence and the time taken to read the corresponding rationale clause sentence. The obtained correlation was a thoroughly nonsignificant -0.02 , disconfirming the suggestion.

7. Since the interpretation of PRO and overt pronouns often differs when they are in the scope of quantified phrases (see Montalbetti, 1984, for example), identifying a stage of parsing in which the two are treated on par would open the door for psycholinguistic studies of LF construction.

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Appendix I
Sentences from Experiment 1
Sentence forms I and II

John lent|borrowed some valuable 19th century books to|from Maria
to read|on vacation|keep Billy from destroying them.

Lynne gave|accepted several eggplants to|from Susan to fix for
dinner|cheer her up.

Jerry sold|bought some old furniture to|from Steve to use in his
new house|help him out.

Janet sent|retrieved her bicycle to|from her sister last week to
ride cross country|get it out of the garage.

Jim mailed|took some money to|from his sister to use for a vacation
|settle their accounts.

Susie handed|obtained a note to|from Ms. Blackwell to give to the
gym teacher|get out of gym class.

James passed|yanked the cartoon to|from Jenny to show to the class
|annoy her.

The boy shoved|stole the skateboard to|from the little girl to ride
down the hill|get her attention.

Sandy pushed|pulled the toy reindeer to|from Bill to put on top of
the Christmas tree|make him play with the other kids.

Kathy threw|snatched the basketball to|from Jane to pass to Tim
|confuse the others.

Jack took|picked up an old car to|from George to put up on blocks
for the winter|keep it out of the rain.

Sally brought|grabbed the dessert plate to|from her mother to pass
around to her guests|help serve the guests.

Sentence form III

The principal chose an older student to go|take to the conference.

The executive selected a new employee to travel|send to Europe.

Sam wanted the robot to perform for|show to his friends.

Sue invited some friends to come meet the new neighbors|introduce
to the new neighbors.

Katie found a friend to accompany her|accompany to the movies.

Mrs. Smith picked out the younger children to help make|treat to
homemade ice cream.

Sentence form IV

Billy programmed the computer to do all|escape doing his homework.

The missionary taught the illiterate woman to read simple passages
to the Bible School|help her read the Bible.

Apparently the teacher called on the loudmouth to lead the rest
|embarrass him in front of the class.

The doctor picked the oldest nurse to train|upset the volunteer
helpers.

The babysitter screamed at Tommy to stop annoying|impress her
friends.

The governess disciplined the children to act like robots|please
her employer.

Appendix 2

Sentences from Experiment 2

Sarah gave a cake to Billy so he ****_DARKNESS_**** would have
something for his birthday party.

Sarah gave a cake to Billy so she ****_DARKNESS_**** could come to
his birthday party.

Sarah accepted a cake from Billy so she ****_DARKNESS_**** would
have something for her birthday party.

Sarah accepted a cake from Billy so he ****_DARKNESS_**** would
come to her birthday party.

Mark lent some camping gear to Tina so she ****_DISCRIMINATION_****
could go camping.

Mark lent some camping gear to Tina so he ****_DISCRIMINATION_****
could go camping with her.

Mark borrowed some camping gear from Tina so he ****_DISCRIMINATION_****
**** could go camping.

Mark borrowed some camping gear from Tina so she
****_DISCRIMINATION_**** could go camping with him.

Lisa sold a car to Jay so he ****_HAPPINESS_**** could drive to
work.

Lisa sold a car to Jay so she ****_HAPPINESS_**** would have
some cash.

Lisa bought a car from Jay so she ****_HAPPINESS_**** could drive to work.

Lisa bought a car from Jay so he ****_HAPPINESS_**** would have some cash.

Keith pushed the poker chips to Fran so she ****_GREATNESS_**** could place a bet.

Keith pushed the poker chips to Fran so he ****_GREATNESS_**** wouldn't be able to place a bet.

Keith pulled the poker chips from Fran so he ****_GREATNESS_**** could place a bet.

Keith pulled the poker chips from Fran so she ****_GREATNESS_**** wouldn't be able to place a bet.

Barbara threw the wallet to Aaron so he ****_INVOLVEMENT_**** would have some money.

Barbara threw the wallet to Aaron so she ****_INVOLVEMENT_**** wouldn't spend her money.

Barbara grabbed the wallet from Aaron so she ****_INVOLVEMENT_**** would have some money.

Barbara grabbed the wallet from Aaron so he ****_INVOLVEMENT_**** wouldn't spend his money.

Stan brought the homework assignment to Mrs. Jones so she ****_EMPTINESS_**** could read it.

Stan brought the homework assignment to Mrs. Jones so he ****_EMPTINESS_**** could get rid of it.

Stan grabbed the homework assignment from Mrs. Jones so he ****_EMPTINESS_**** could fix it.

Stan grabbed the homework assignment from Mrs Jones so ****_EMPTINESS_**** couldn't read it.

Maria sent her clothes to her father so he ****_INDICATION_**** could have them cleaned.

Maria sent her clothes to her father so she ****_INDICATION_**** wouldn't have to clean them.

Maria retrieved her clothes from her father so she ****_INDICATION_**** could have them cleaned.

Maria retrieved her clothes from her father so he ****_INDICATION_**** wouldn't have to clean them.

Paul took some medicine to Donna so she ****_LONELINESS_**** could get feeling better.

Paul took some medicine to Donna so he ****_LONELINESS_**** could help her feel better.

Paul picked up some medicine from Donna so he ****_LONELINESS_**** could get feeling better.

Paul picked up medicine from Donna so she ****_LONELINESS_**** could help him feel better.

Lynne gave a present to Michael because he ****_READINESS_**** was so upset.

Lynne gave a present to Michael because she ****_READINESS_**** was so stupid.

Lynne accepted a present from Michael because she ****_READINESS_**** liked him so much.

Lynne accepted a present from Michael because he ****_READINESS_**** liked her so much.

John lent some books to Mary because she ****_FOOLISHNESS_**** wanted to read them.

John lent some books to Mary because he ****_FOOLISHNESS_**** wanted her to read them.

John borrowed some books from Mary because he ****_FOOLISHNESS_**** wanted to read them.

John borrowed some books from Mary because she ****_FOOLISHNESS_**** wanted him to read them.

Nina sold some old furniture to Jerry because he ****_STEADINESS_**** wanted to refinish it.

Nina sold some old furniture to Jerry because she ****_STEADINESS_**** didn't want to refinish it.

Nina bought some old furniture from Jerry because she ****_STEADINESS_**** wanted to refinish it.

Nina bought some old furniture from Jerry because he ****_STEADINESS_**** didn't want to refinish it.

Bill pushed the toys to Sandra because she ****_INNOVATION_**** wanted them.

Bill pushed the toys to Sandra because he ****_INNOVATION_**** didn't want them.

Bill pulled the toys from Sandra because he ****_INNOVATION_**** wanted them.

Bill pulled the toys from Sandra because she ****_INNOVATION_**** didn't want them.

Kathy threw the basketball to Tom because he ****_REFINEMENT_**** could shoot it.

Kathy threw the basketball to Tom because she ****_REFINEMENT_**** couldn't shoot it.

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Kathy grabbed the basketball from Tom because she ****_REFINEMENT_
**** could shoot it.

Kathy grabbed the basketball from Tom because he ****_REFINEMENT_
**** couldn't shoot it.

Tom brought the dessert plate to his mother because she
****_HESITATION_**** yelled at him.

Tom brought the dessert plate to his mother because he
****_HESITATION_**** yelled at her.

Tom grabbed the dessert plate from his mother because he
****_HESITATION_**** was angry.

Tom grabbed the dessert plate from his mother because she
****_HESITATION_**** yelled at him.

Janet sent her bicycle to her brother because he
****_ATTACHMENT_**** needed it.

Janet sent her bicycle to her brother because she
****_ATTACHMENT_**** didn't need it.

Janet retrieved her bicycle from her brother because she
****_ATTACHMENT_**** needed it.

Janet retrieved her bicycle from her brother because he
****_ATTACHMENT_**** didn't need it.

Jack took some old records to Sally because she ****_ROUGHNESS_****
wanted to hear them.

Jack took some old records to Sally because he ****_ROUGHNESS_****
wanted her to hear them.

Jack picked up some old records from Sally because he
****_ROUGHNESS_**** wanted to hear them.

Jack picked up some old records from Sally because she
****_ROUGHNESS_**** wanted him to hear them.