COREFERENCE PROCESSING DURING SENTENCE COMPREHENSION

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Submitted to the Department of Brain and Cognitive Sciences
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ABSTRACT

This dissertation investigates how the human language processor determines coreferential relations among elements within a sentence during sentence comprehension. This dissertation consists of three self-contained chapters. The first two report results of experimentation. The first chapter addresses questions concerning coreference between an antecedent and a phonologically null element; specifically, which types of information are necessary both to determine the presence of an empty element and to identify its antecedent. Results indicate that only information relating to structure and to structural constraints on coreference are available for these processes. The second chapter examines the mechanisms which underlie the coreference of overt anaphoric elements—pronouns and reflexives—with their antecedents. The evidence suggests that anaphoric elements reactivate potential antecedents from the prior clause. This set of candidate antecedents is initially restricted by two different types of information: a referent is reactivated if 1) syntactic constraints on coreference are not violated, and 2) its number and gender specifications match those of the pronoun. The third chapter provides a review of recent on-line research on coreference processing. The evidence supports a model of processing in which there are modular subprocesses that have access only to a restricted domain of information.
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PREFACE

A brief note about format is in order. This dissertation contains three chapters that are related, yet self-contained. Since each of the chapters was designed to be readable as an independent piece, I refer to other chapters just as I would to other works: where relevant, results are either alluded to or summarized. For accessibility, endnotes and tables appear at the end of each chapter. All references appear together following Chapter 3. Stimulus materials are presented in appendices after the references.
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Chapter 2

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CHAPTER 1: RE-ACTIVATING ANTECEDENTS OF EMPTY CATEGORIES DURING PARSING
1.1 Introduction

Much of the recent research on sentence understanding has focussed on identifying the types of information available to the parser during sentence processing, and, on the assumption that there is information that is inaccessible, examining the operation of the parser in the absence of potentially useful information.

One approach to studying these issues has been to examine how the parser operates in cases of syntactic ambiguity. An example of a syntactically ambiguous string is a sentence fragment such as, "While Mary was mending the socks...". Here, the noun phrase "the socks" may function as the object of the verb "mend" (as in "While Mary was mending the socks, Bill took a nap."), or "the socks" may be the subject of a subordinate clause (as in "While Mary was mending, the socks fell on the floor."). Sentences containing ambiguity of this sort abound in natural language; the parser must have a procedure for dealing with them. Several alternatives have been proposed. In their strong form, these are as follows: 1) Analysis is delayed until disambiguating information is encountered (e.g. Chodorow, 1979). 2) Multiple structures are constructed in parallel (e.g. Kurtzman, 1985, Gorrell, 1987). 3) The parser commits itself immediately to one analysis, and decisions are made according to (a) parsing "strategies", which are based on frequency of occurrence of particular structures (e.g Bever, 1970, Frazier, 1979), and/or (b) idiosyncratic properties of individual lexical items, such as verb subcategorization frames (e.g. Fodor, Bever, and Garrett 1967).
Support for the third alternative comes from how listeners process "garden-path" sentences, sentences containing structurally ambiguous material that is initially misanalyzed, so that the hearer is "led down a garden path". For example, the sentence, "While Mary was mending the socks fell on the floor" may initially be misconstrued and require re-analysis. The reason that the fragment, "While Mary was mending the socks..." is ambiguous is that the verb "mend" takes multiple subcategorization frames: "mend" subcategorizes for either a noun phrase complement or no complement (i.e. "mend" may be used either as a transitive or an intransitive verb). If, upon encountering the noun phrase "the socks", the parser either delayed analysis or constructed two parse trees in parallel, misanalysis should not occur. On the view that the parser commits itself immediately to a single analysis (the so-called "garden path theory"), this sentence is initially analyzed with the noun phrase "the socks" as object of the verb "mend". This analysis is based on the "parsing strategy" of "late closure", which asserts that, rather than begin a new clause, the parser will incorporate as much material as possible into the current clause (see Frazier, 1978, for a formulation of this principle). Thus, the noun phrase "the socks" is analyzed as being part of the clause, "While Mary was mending...", leaving the following tensed verb "fell" without a subject (which, presumably, triggers reanalysis of the sentence).

Assuming the "garden path" theory, Frazier, Clifton and Randall (1983) (henceforth FCR) examined how subjects responded to embedded infinitival sentences with "empty subjects" (or "PRO"; see Chomsky, 1981, and the references cited there). Sentence pairs such
as the following were presented (subscripts are used to indicate coreference between PRO and its antecedent):

1a) Everyone liked the woman who the little child$_1$ begged PRO$_1$ to sing those songs for.

1b) Everyone liked the woman$_1$ who the little child begged PRO$_1$ to sing those songs.

In (1a) PRO is ultimately identified, or coindexed, with "the little child", whereas in (1b) it is coindexed with "the woman". However, it is only after the entire sentence is processed that the construal of PRO becomes apparent; at the point where the infinitive is first analyzed, either prior noun phrase (i.e. "the woman" or "the child") is a potential antecedent for PRO. On the FCR view, the parser must immediately commit itself to a single analysis, therefore, it must have some basis for analyzing ambiguous material one way and not another. 2

FCR hypothesized that the parser processes ambiguities of this sort according to the "Most Recent Filler Strategy" (hereafter, the MRFS), which states that: "a detected gap is initially and quickly taken to be co-indexed with the most recent potential filler" (p. 196). Such a strategy is motivated by the observation that in sentences containing multiple empty NPs, such as, "Which pot$_i$ is this soup$_j$ easy to cook ____$_j$ in ____$_i$." (p. 195), the first "gap" must be linked to the nearest preceding NP. 3

FCR also cite developmental data: young children have been observed to interpret the most recent filler as antecedent of PRO in sentences containing "subject control verbs" like promise, as in "Mary promised Sue PRO to get the book", as well as in sentences containing "object control verbs", such as tell, as in "Mary told Sue PRO to get the book". 4
For sentence (1a) above, where the implied subject of "to sing" is the most recent noun phrase, "the child", the MRFS happens to produce the correct analysis, one that coincides with the final interpretation of the sentence. However, for (1b), where the understood subject is the "distant" filler, "the woman", the MRFS gives rise to an incorrect structural analysis, and this sentence would require re-analysis. FCR predict that if the MRFS is operative during sentence processing, sentence (1a) ought to be easier to process than (1b).

FCR make a further prediction: interestingly, they expect a similar pattern of results for sentences containing unambiguous verbs, such as "start and "force", as in the following:

2a) Everyone liked the woman who the little child started PRO to sing those songs for.

2b) Everyone liked the woman who the little child forced PRO to sing those songs.

FCR suggest that the rules that dictate coreference of PRO with an antecedent (referred to as "control theory"; see Chomsky, 1981, Manzini, 1983, Koster, 1984, Williams, 1987) may simply not be available to the parser, which must operate in the absence of such information. This is a reasonable hypothesis, given the distinction that may be made between constraints that relate to string creation and those that apply to relations among constituents within a string, such as coreference (Chomsky, 1981, Olbrei & Forster, 1984). If the sentence parser is primarily concerned with building structure, then it may well be that it does not have access to "control information". On these grounds, FCR predict that the processing of sentences (2a,b)
above will pattern with sentences (1a,b): (1a) and (2a) will be easier to process than (1b) and (2b).

In sentence (2a), as in (1a), the subject of the infinitive, PRO, is identified with the most recent filler, "the child", whereas in (2b), and (1b), PRO is linked to the distant filler "the woman".

Again, the prediction is that the application of the MRFS will result in misanalysis of sentences (1b) and (2b), and sentences of this type will have to be re-analyzed. Since reanalysis burdens the processor, these sentences should be more difficult to understand. To test this prediction, FCR had subjects read sentences like (1a,b) and (2a,b) presented one word at a time on a CRT screen. At the end of the sentence, subjects were to indicate as quickly as possible whether they had understood the sentence or whether they would normally have had to go back and re-read it. "Recent Filler" sentences (such as (1a) and (2a)) and "Distant Filler" sentences ((1b) and (2b)) were compared on two measures: 1) percentage of trials for which subjects felt they had immediately understood the sentence; and 2) reaction times for sentences so classified. On both measures, recent filler sentences were "easier" to process than distant filler sentences. This was the case both for the ambiguous and unambiguous verbs. (These results were replicated in Clifton & Frazier, 1986, and replicated for the ambiguous verbs by Crain & Fodor, 1986.) The results obtained invite the conclusion that the MRFS is indeed applied during the processing of sentences containing empty subjects.
Even though the FCR results are consistent with the existence of a parsing strategy such as the MRFS, there is good reason to doubt that such a strategy actually operates during parsing. FCR suggest that the partition between phrase structure rules and constraints on coreference (Chomsky, 1975) is reflected in discrete parsing operations. This division is, in fact, the basis for the supposition that the parser does not have access to control information. This reasoning seems sound. But this supposition does not entail the further proposal that the parser immediately assigns an antecedent to PRO. While a parsing strategy such as "late closure" may be necessary in order for structure-building to proceed in the face of ambiguity, the MRFS is not necessary for further syntactic analysis; there are no subsequent parsing decisions which rest on determining the antecedent of PRO. If the parser is solely concerned with building structure (a view we share with FCR), it can do so without establishing the identity of PRO. To suggest otherwise is akin to proposing that overt elements such as pronouns must immediately be identified with an antecedent for parsing to proceed. Clearly, in both cases, the correct antecedent is eventually identified. However, in contrast to the assumptions made by FCR, identifying the antecedent of PRO need not occur immediately. There is little doubt that listeners ultimately figure out which noun phrases play which roles in a sentence, including determining which noun phrase also serves as the subject of an untensed clause. The question is whether coreference of PRO is computed immediately.

The purpose of the current research is to test the MRFS during sentence comprehension. We used an on-line technique that has
been shown by Swinney, Ford, and Bresnan (1988) to be sensitive to the presence of empty NP's. Using a cross-modal priming paradigm to provide a measure of lexical access, Swinney et al. found reactivation of the antecedent of a "trace" (i.e. an empty object) at a point where the trace would be represented in the syntactic representation. For example, there is a trace following the embedded verb in the sentence, "the policeman saw the boy that the crowd at the party accused trace of the crime". Associates of "boy" and "crowd" (and unrelated words matched in length and frequency to the associates) were probed at several points in the sentence: 1) after "party"; 2) after "accused"; and 3) 300 msec. downstream from point (2) (approximately 1.5 syllables after point (2)). The level of activation of the antecedent of the trace, that is, "boy"\(^5\), was found to be greatest at point (2), exactly where a trace would be represented. One may conclude, then, that a phonetically null NP may trigger reactivation of its antecedent. Using this procedure to test coreference assignments for PRO, we predict the following: if the MRFS is applied during parsing, we ought to obtain, for all sentence types, priming for the most recent referent. Thus, we would expect priming of a referent that is the actual antecedent of PRO in sentences such as (1a, 2a) above, and priming of that same referent, though it is not the correct antecedent, in sentences such as (1b, 2b) above.\(^6\) Two experimental series testing this and related questions are reported below.
1.2 EXPERIMENTAL SERIES 1

1.2.1 EXPERIMENT 1a

METHODS

Subjects.

Forty Tufts University undergraduates participated in this experiment for course credit. All were native English speakers with normal or corrected vision and normal hearing.

Materials and Procedure.

We used constructions similar to those used by FCR. An example of a sentence pair is as follows (note: coreference is indicated by indices):

That's the actress$i$ that the dentist$j$ from the new medical center in town...

1) had invited $t_i$ PRO$i$ to go to the party
2) had hesitated PRO$j$ to go to the party with $t_i$

We did not use verbs such as "beg" or "ask", which allow multiple subcategorization frames, since, initially, we wanted to test the strongest form of the MRFS. That is, we wanted to determine whether or not the MRFS was applied in cases where there was no temporary ambiguity, since, if there was no priming of the most recent filler in sentences such as (2) ("...the dentist...hesitated PRO to go...") , then there would be little point in going on to test the ambiguous cases. Hence, we used verbs that were either intransitive in these constructions (e.g. "hesitate", or "start") or transitive (e.g. "force" or "invite"), but not both (e.g. "choose"). The set of intransitive verbs was further broken down into two
groups. One group was "purely" intransitive; these verbs ("hesitate", for example) do not subcategorize for noun phrase complements, the other group (consisting of verbs such as "decline") subcategorizes for either a NP complement or a sentential complement. A feature of the second group is that when they do take a noun phrase complement, this noun phrase is normally inanimate (for example, "decline the invitation", but not "decline the actress"), so that in the constructions used here, these verbs appear to be intransitive (note the nonsensical interpretation of the following sentence if "the actress" is linked to a trace: "That's the actress that the dentist declined t₁...".). Although FCR used both types of "intransitive" verbs in their "unambiguous" intransitive verb condition, we suspected that this contrast between subgroups of "intransitive" verbs could well yield different activation patterns in the on-line task.

A further difference between our stimuli and those in the FCR study was that in our sentences, a phrase intervened between the most recent potential antecedent and the infinitive. In the example above, the phrase, "from the new medical center" separates "the dentist" from the verb phrase. This was done to ensure that when we probed for the activation of "dentist" at PRO, we were not simply measuring residual activation. A study reported in Tanenhaus, Carlson, and Seidenberg (1985), indicates that an item presented auditorily will generally cease to yield priming after approximately four to seven words. Thus, in order to be able interpret any obtained priming of the most recent potential antecedent, we had to be sure that it was sufficiently distant from the probe point.
Twenty-four experimental sentences were constructed, each with an embedded clause containing an intransitive verb in one version, and a transitive verb in the other. Sixty-eight filler sentences were also created. These varied in complexity, and included a number of passive, cleft, and pseudocleft sentences. In all, there were ninety-two sentences, the first eight of which contained no experimental sentences, and which were considered to be practice items. Sentences were recorded on a TEAC tape recorder by one of the experimenters (LO). The sentences were then digitized at a sampling frequency of 20k. Both versions of the experimental sentences were recorded, and then "spliced" (using signal processing software) such that both endings followed the same version of the matrix clause. This was done so that possible differences in the presentation of the matrix clause would not affect response time. To avoid any possibility of the experimental sentences standing out, all the filler items were also subjected to the process of digitization. Sentences were then re-recorded onto two separate audio tapes, each of which contained different versions of the experimental sentences. These sentences were counterbalanced across tapes so that each tape contained equal numbers of sentences with transitive verb endings and intransitive verb endings (twelve of each).

Four presentation lists were also constructed. These lists consisted of target items on which subjects were to make a lexical decision. For the experimental sentences, the word was either 1) related to the distant filler; 2) related to the recent filler; 3) a control word (matched for length and frequency) to the item related to the distant filler; OR 4) a control word for (2). These four
target types were counterbalanced across presentation lists so that each list contained six of each type of target. Filler sentences had either a real word target or nonword target associated with it. Of the 92 targets total, 46 of these were words (24 of which were experimental items), and 46 were pseudowords.

At some point during each sentence, a 1000 Hz. signal was recorded onto the left channel of the tape. This signal—inaudible to subjects, who heard only the right channel—was read by a Uher 437 diapilot, which then signalled a DEC 11/23 computer to 1) present the appropriate item on a CRT screen which was positioned in front of the subject, and 2) initiate a timing routine that was terminated by the subject’s button press. For experimental sentences, the signal was recorded at the offset of the word "to" in the embedded clause, as shown in the example below (the probe point is indicated by "#”). The location of the signal varied randomly in the filler sentences.

That's the actress_{i} that the dentist_{j} from the new medical center in town...

1) had invited t_{i} PRO_{i} to # go to the party
2) had hesitated PRO_{j} to # go to the party with t_{i}

Sentences were presented auditorily through headphones. At the probe point, subjects made a lexical decision to either a word or nonword which appeared for a period of 300 msec. on the CRT screen, and pressed a button labelled "WORD", or "NONWORD". To ensure that subjects did not simply focus all their attention on the lexical decision task, a paraphrase task was included. Subjects were told at the outset that a number of sentences would be followed by the sound of a bell, and that the bell was a signal for subjects to write down "all they could remember" about the sentence they had heard just
prior to the bell. They were also told that since there was no advance warning of an upcoming bell, they were to listen carefully to each sentence. This paraphrase task was included only to encourage subjects to attend to the sentences, and recall performance was accordingly not considered in compiling our results.

RESULTS

Prior to analysis, missing data points and responses greater than 2000 msec. were replaced by the subject's mean reaction time for the 3-way interaction described below. Such responses accounted for 5% of the total.

Two analyses of variance were performed, the first treating subjects as a random variable ($F_1$), the second treating items as a random variable ($F_2$). Both analyses revealed a significant main effect of target type (related vs. unrelated) ($F_1(1,32) = 27.24$, $p < .0001$; $F_2(1,23) = 14.04$, $p = .0011$). A significant target by referent interaction was found for $F_1$ ($F_1(1,32) = 6.26$, $p = .018$). No other effects or interactions reached significance.

Table 1 presents mean reaction times in milliseconds (collapsed across subjects and items) for the crucial 3-way interaction of target type (related vs. unrelated to a referent), referent (recent vs. distant), and sentence type (contains a transitive vs. intransitive verb in the embedded clause). This interaction was non-significant ($F_1(1,32) = .64$ and $F_2(1,23) = .42$). These data were subjected to four correlated t-tests to determine whether the means for related targets were significantly lower than means for unrelated targets. As Table 1 shows, reaction times were
facilitated for the distant filler after both transitive verbs 
$(t_1(39) = -3.26, p = .002 \text{ (throughout, } p \text{ values are for two-tailed } t\text{-}
\text{tests); } t_2(23) = -2.67, p = .014)$, and intransitive verbs $(t_1(23) =$
\text{-}3.59, $p = .001$; $t_2(23) = -2.11, p = .046$). Response times to
associates of the recent filler were not significantly faster than to
unrelated controls following either transitive verbs $(t_1(39) = -0.2,$
$p = .843$; $t_2(23) = -0.013, p = .897$) or intransitive verbs $(t_1(39) =$
\text{-}1.73, $p = .092$; $t_2(23) = -1.06, p = .299$).

Insert Table 1 about here

DISCUSSION

The hypothesis that the MRFS operates during sentence
processing would predict priming for items related to the most recent
potential antecedent in both sentence types. Clearly, this
prediction is not supported by the data. Instead, there is
significant priming of the distant filler but no significant priming
of the recent filler.

Considering first the sentences containing transitive verbs,
such as "invite", the most parsimonious interpretation of the pattern
of priming obtained, given the findings by Swinney et al., is that a
trace is postulated following the embedded verb, and that it is this
trace that gives rise to the activation of the distant filler. Given
that the antecedent for trace and PRO in these particular
constructions is identical (e.g. "That's the actress that the
dentist had invited \( t_i \) PRO to go out dancing"), and given the contiguity of trace and PRO in these constructions, it is unclear whether or not PRO triggers reactivation of its antecedent.

The priming patterns obtained for sentences containing intransitive verbs such as "hesitate" ought be illuminating in this regard, since a trace does not appear until the end of the sentence. However, a similar priming pattern emerged: only the distant potential filler was activated. There are a number of quite plausible explanations for such a result. One is that there are cues, such as the presence of a relative pronoun, in relative clause constructions (i.e. "There's the actress that...") that could signal the parser that a trace is to be represented at some later point in the sentence, and so the parser posits a trace at the first point possible; in these sentences, after the first verb it encounters, regardless of whether or not that verb can take a NP complement. Hence, priming of distant referent in these instances reflects the reactivation of the antecedent of an erroneously postulated trace. Alternatively, given the relative clause construction, and the recognition that there is an upcoming trace, it is possible that, once accessed, "actress", which is to be linked to the trace, remains activated until a trace is hypothesized (Wanner and Maratsos, 1979). A further possibility is that any noun phrase in topic position may be so salient that its activation level may either remain high throughout the sentence, or undergo a slower than normal decline in activation.

The first explanation predicts that probing at some point between the distant referent and the original probe point will show
no priming of the distant referent: if priming of this referent is the result of the parser mistakenly representing a trace, then there should be no priming of the distant referent up until the point where a trace could be represented, that is, after the embedded verb.

The last two hypotheses—but not the first one—predict that probing at some point between the distant referent and the original probe point ought to show priming of that referent. Further, if the distant antecedent remains active until a trace is encountered, probing downstream from the original probe point should show priming in the intransitive verb condition, since, in this condition, a trace does not occur until the end of the sentence.

Probing downstream from the initial probe point might also show reactivation for the antecedent of PRO. There is evidence that subject pronouns cause reactivation of their antecedents with the greatest magnitude of priming approximately 500 msec. following presentation of the pronoun (MacDonald, 1987, Fodor, Garrett, Swinney, cited in Swinney, Ford, and Bresnan (1988). Since PRO is functionally equivalent to a subject pronoun—it occurs in a clause separate from its antecedent and can refer to either the subject or object of the preceding clause—it could plausibly exhibit similar characteristics with respect to priming of its antecedent. Therefore, the downstream point could well reveal priming of the appropriate antecedent (i.e. the recent referent) in sentences containing intransitive verbs.

Experiments 1b and 1c, presented together below, were conducted to explore these possibilities.
1.2.2 EXPERIMENTS 1b and 1c.

METHODS

Subjects. Two groups of forty Tufts undergraduates participated. Again, all were native English speakers and all had normal or corrected vision and normal hearing.

Materials and Procedure. The materials and procedure were identical to those used in Experiment 1a, except for differences in probe point. As shown in the example sentences below, in Exp. 1b, probes appeared just after the phrase modifying the recent potential antecedent; in Exp. 1c, targets for lexical decision appeared 300 msec. after the initial probe point (that is, 300 msec. after "to" in the infinitive). 8

That's the actress that the dentist from the new medical center in town # had invited to go to # the party.
Exp. 1b                      Exp. 1c

That's the actress that the dentist from the new medical center in town # had declined to go to # the party with.
Exp. 1b                      Exp. 1c

RESULTS

Data were combed as for Exp. 1 and subjected to analyses of variance with subjects (F₁) and then items (F₂) as a random factor.

For Exp. 1b, in which the probe point preceded the embedded verb, the analysis of variance with subjects as a random variable showed only the following interactions to be significant: list x referent (F₁(3,32) = 4.52, p = .0094); list x referent x target (F₁(3,32) = 2.8904, p = .0506); tape x list x sentence type x
referent x target \( (F_1(3,32) = 4.2259, \ p = .0126) \). The items analysis yielded no significant main effects or interactions.

Relevant means are presented in Table 2. Pairwise comparisons of means for related vs. unrelated target types within referent and sentence type showed no significant differences whatsoever, on either subjects or items analyses.

Insert Table 2 about here

For Exp. 1c, subjects analysis showed a significant main effect of target \( (F_1(1,32) = 18.96, \ p = .0001) \), and the following interactions involving target: list x target \( (F_1(1,32) = 3.75, \ p = .0204) \); tape x list x target \( (F_1(3,32) = 3.802, \ p = .0194) \); tape x list x sentence type x target \( (F_1(3,32) = 6.2915, \ p = .0018) \); tape x sentence type x referent x target \( (F_1(1,32) = 10.175, \ p = .0032) \); tape x list x sentence type x referent x target \( (F_1(3,32) = 4.9221, \ p = .0064) \). These effects are largely uninterpretable due, in part, to the fact that subjects were nested within the tape and list variables (i.e. any given subject was exposed to only one combination of tape and list); hence, it is impossible to ascertain whether the observed interactions are due to differences between groups of subjects or to actual differences between stimulus tapes and/or target lists. Further, there is no sensible interpretation of these effects; one assumes no significant differences between subjects and no differences between tapes or lists. For ANOVA\(_1\), no other main
effects or interactions were significant. ANOVA2 showed no significant effects or interactions.

The relevant data, derived from the 3-way interaction of target (related/unrelated), referent (distant/recent), and sentence type (contains a transitive/intransitive verb), are displayed in Table 3. The pattern of priming found here is much the same as for Exp. 1; the distant referent is primed in both sentence types. However, the priming is significant only following transitive verbs, and only with subjects as a random factor (t₁(39) = -2.825, p = .007, but t₂(23) = -1.576, p = .129 (following intransitive verbs, t₁(39) = -1.982, p = .055). Priming for the recent referent is entirely nonsignificant.

Insert Table 3 about here

DISCUSSION

The pattern of priming across probe points for both sentence types is summarized below (magnitude of priming for the distant filler ("DF"), "actress", and the recent filler ("RF"), "dentist", appears beneath each probe point (#) in the two sentence types; scores for the correct antecedent of PRO are shown in italics):

That's the actress₁ that the dentist₂...

1) # had invited t₁ PRO₁ to # go to # the party

| DF: 30 | 75* | 57* |
| RF: 6  | 4   | 12  |
2) # had hesitated PRO$_j$ to # go to # the party with t$_1$

\[
\begin{array}{llll}
\text{DF:} & 12 & 71^* & 48 \\
\text{RF:} & 28 & 36 & 21 \\
\end{array}
\]

Exp. 1b of this experiment was carried out to test whether or not the distant filler, being in topic position, was simply active throughout the sentence, or whether it was reactivated following the lower verb. Results demonstrate that at a point upstream from the initial probe point, there was no significant priming of the distant filler for either sentence type. This indicates that the distant referent is indeed re-activated following the embedded verb. The question remains, however, why this referent would be reactivated following intransitive verbs.

A plausible explanation is that verb subcategorization information is unavailable (or not immediately available) to the parser. Thus, having processed the relative clause modifying the distant referent, the parser posits a trace at the first opportunity it has, i.e. after the first verb it encounters, regardless of the structural properties of that verb. But a parser that ignores verb subcategorization features is going to make frequent attachment errors. Identical--erroneous--analyses will be produced for a likely garden-path sentence such as, "While Mary watched the child played." and a seemingly unproblematic one, such as, "While Mary gazed the child played." Admittedly, the possibility that the parser is blind to subcategorization properties cannot be rejected on the basis of intuition about whether or not our parsers have taken a wrong turn; conscious reflection, after all, has little bearing on unconscious processing. However, there is a growing body of empirical evidence
that subcategorization information is accessed on-line, and used for parsing decisions (Gorrell, 1987, Chodorow, 1979).

It is possible that the subcategorization properties of verbs are accessible for attachment decisions, but not for the postulation of trace in constructions in which an upcoming trace may be anticipated, for example, relative clause structures. As an example of the former case, if the parser is presented with the sentence, "While Mary watched the child...", once "the child" is determined to be a noun phrase, this NP could be attached to the verb phrase containing the verb "watch", or it could begin a new clause. At this point, the parser consults the subcategorization information associated the verb "watch", and if "watch" takes a NP complement, the NP "the child" is attached to the VP. On the other hand, since relative clause constructions contain cues that there is an upcoming trace, a NP node (dominating the trace) may be attached to the VP as soon as the verb occurs. (Of course, subsequent examination of the structural properties of the verb may indicate erroneous attachment of the NP, and reanalysis will be required.) However inelegant, such an explanation does present a feasible account of the findings.

There is a sensible alternative. It is quite possible that priming of the distant antecedent following intransitive verbs is entirely due to the subset of verbs which take inanimate noun phrase complements. Recall that the intransitive verbs used in this study were of two types: 1) verbs which do not take noun phrase complements; 2) verbs which can take noun phrase complements, but whose NP complements tend to be inanimate. The latter are the verbs which behave intransitively in these sentences, but are not
absolutely intransitive. Analysis of the subgroups defined by the two
types of intransitive verbs indicated that priming of the distant
referent was indeed greater following this second group of
intransitive verbs, yet not significantly so (see Table 4). Given
the small number of items--only twelve--in the analysis, lack of
significance might simply reflect lack of power. To better test
this, a modified version of Exp. 1a was conducted (see Nicol and
Osterhout, 1988). Instead of the initial contrast between transitive
verbs (such as "force") and intransitive verbs (such as "hesitate"),
the two types of "intransitive" verbs (e.g. "hesitate" vs. "decline")
were contrasted. Otherwise, the materials are identical to those in
Exp. 1a.

Insert Tables 4 about here

Nicol and Osterhout found significant priming in one cell
only: for the distant referent following those verbs that take NP
complements (such as in the sentence, "That's the actress that the
dentist planned to invite to the party."). These data support the
hypothesis proposed above that the pattern of priming following
intransitive verbs is due not to a blindness to subcategorization
properties, but rather, to the fact that half of these verbs do
actually subcategorize for a noun phrase.

As for the set of purely intransitive verbs, do activation
patterns reveal anything about whether or not PRO causes its
antecedent to be reactivated? Not in any straightforward way.
Following the "pure" intransitive verbs, the distant referent does not appear to be primed at all, whereas for the recent referent, there is 33 msec. facilitation for the related target. This apparent priming of only the appropriate antecedent of PRO is not, however, significant. Further, since the magnitude of facilitation for the recent referent is roughly equal following both verb types, it is possible that this facilitation merely reflects residual activation of that referent. Therefore, while the data are not entirely clear with respect to PRO, they do not point to an immediate reactivation of only the appropriate antecedent.

Exp. 1c--in which the probe point was 300 msec. downstream from the initial point--was intended to explore the following: 1) the possibility that the distant referent would remain active until a trace (to which it could be coindexed) was proposed; and 2) the possibility that the antecedent for PRO might be reactivated, in the intransitive verb sentences, after some delay.

With respect to the first possibility, the finding in Exp. 1b that there is no significant priming of the distant referent at a point intervening between the initial probe point and the referent itself argues against the continued activation hypothesis.

As for the second question, that, in the intransitive verb condition, there may be activation of the correct antecedent of PRO after a brief lapse of time, there is no indication, 300 msec. downstream, that the appropriate antecedent of PRO in these sentences (i.e. the recent referent) is reactivated. In fact, the absolute magnitude of priming for this referent is less than at the initial
probe point, and the p values corresponding to the relevant t-tests are greater. One would expect that eventually the erroneously posited trace following the intransitive verb (and perhaps coindexed with PRO) would be registered, and the string reanalyzed. Given the results of Exp. 1c, however, it is clear that this process takes longer than 300 msec. Hence, at the downstream probe point, the activation patterns for the two sentence types are roughly equivalent: The postulation of a trace—correctly or not—following the embedded verb has triggered reactivation of the antecedent of the trace. The activation level of the antecedent diminishes over time; 300 msec. after the initial probe point, this level has decreased.

At this point, we might have continued this line of research, probing further and further downstream. Doing so may have revealed whether or not, and at what point, PRO reacts its antecedent, and may have been illuminating regarding the time course of reanalysis subsequent to erroneous syntactic analysis. We opted, however, for a more direct approach to the question of whether PRO triggers reactivation of its referent: we modified the sentences in such a way as to avoid the trace-PRO sequence. By eliminating the effects of trace, we hoped to obtain a clearer picture of the properties of PRO with respect to activation of its antecedent. The details of this set of experiments are given below in Exp. II.

1.3 EXPERIMENTAL SERIES 2

1.3.1 EXPERIMENT 1a
Since the sentence constructions used in Experiment 1 contained a trace-PRO sequence, it was difficult to obtain an unequivocal picture of the reactivation patterns produced by the presence of the empty subject. The purpose of the present experiment is to explore whether, and when, PRO triggers activation of its antecedent.

To examine the properties of PRO in isolation, we used sentences in which the antecedent of PRO was either the first-mentioned or second-mentioned referent in the matrix clause, depending upon whether the matrix clause was active or passive. Consider, for example, the following pair of sentences:

The actress invited the dentist from the new medical center in town PRO$_i$ to go to the party at the mayor's house.

The actress$_i$ was invited by the dentist from the new medical center in town PRO$_i$ to go to the party at the mayor's house.

In the first sentence, the antecedent of PRO is the "recent filler", the dentist; in the second, it is the "distant filler", the actress.

METHODS

The methods used here are not substantially different from those used in Experiment 1.

Subjects. Thirty-two Tufts University undergraduates, selected on the criteria given above, participated in this part of the experiment.

Materials and Procedure. The experimental sentences used in this study were modified versions of those used in Experiment 1. As in
the example above, two versions of each experimental sentence were
created so that one began with an active matrix clause, the other
with a passive matrix clause. The same embedded clause was used in
both versions, and began with an infinitive verb. The embedded
clause was identical to its original in Experiment 1, except that an
additional phrase was added to the end to lengthen the sentence.
This was done so that, if necessary, we could probe at various points
downstream from the original probe point and still remain within the
sentence. Filler sentences were roughly equal in complexity to the
experimental sentences and described scenarios at the same level of
detail. Of the total 92 sentences, 24 were experimental; of the 68
fillers, 8 were practice trials.

Four targets were associated with each sentence: two of the
targets were related to the two referents; the other two were
control words for the related items. Target types were
counterbalanced across target lists so that each list contained equal
numbers of each type of target. Of the 92 target items, 46 were real
words and 46 were non-words. Twelve of the 46 word targets were
items that were related to one of the nouns in the sentence.

Again, two audio tapes were made, each containing one version
of each experimental sentence. Sentence types were balanced such
that each tape contained twelve active matrix sentences and twelve
passive matrix sentences. In the experimental sentences, a 1000 Hz.
tone was recorded onto the second channel immediately following the
to of the infinitive verb; in the filler sentences, the location of
the tone varied randomly.
Sentences were presented auditorily through headphones. At the onset of each sentence, a fixation cross appeared on the CRT screen in front of the subject, and remained on until a target item appeared. Subjects then made a lexical decision to that target, and pressed the appropriately labelled button. Subjects were asked to attend to both tasks: listening carefully to the sentences, and pressing buttons quickly and accurately. To keep subjects listening to the sentences, they were asked to write down every sentence which preceded a bell. There were 6 such instances, four of which involved experimental sentences.

RESULTS

Missing data and reaction times greater than 2000 msec. were replaced by the subject's mean for that condition. This affected approximately 5% of all the data collected.

Two ANOVA's were performed, one treating subjects as a random factor, the other treating items as a random factor. Neither ANOVA revealed any significant main effects or interactions (F < 1 in all cases). Table 5 presents the means for related vs. unrelated items for each sentence type and for each referent, collapsed across subjects and items. T-tests performed on these means (comparing related and unrelated items) were uniformly non-significant (p > .1 throughout).

______________________________________________________________

Insert Table 5 about here

______________________________________________________________


DISCUSSION

At the first point in the sentence where an empty subject is discernable, that is, just after to in the lower clause, there is no evidence that an antecedent has been reactivated. As pointed out above, however, there may be a delay in reactivating prior referents. Hence, in Experiments 2b - 2e below, we probe at successive points following the initial probe point.

1.3.2 EXPERIMENTS 2b - 2e

METHODS

Subjects.

Four groups of thirty-two subjects participated. All were native English speakers and all had normal or corrected vision and normal hearing.

Materials and Procedure.

Materials and procedure are identical to those of Exp. 2a. The point in the sentence at which we probed for activation of antecedents varied as follows. With reference to the initial probe point: the second point was 500 msec. later; the third, 1000 msec.; the fourth, 1200 msec.; and the fifth 1500 msec. later. The approximate positions of the probe points are indicated in the sentence below.
The actress invited the dentist$_1$ from the new medical center in town PROC$_1$ to go to the party at the mayor's house. Exp. 2a Exp. 2b Exp. 2c Exp. 2d Exp. 2e

RESULTS

Throughout Exp.s 2b - 2e, missing data and response times greater than 2000 msec. were replaced by the subject's mean for that condition. (Such data accounted for 4% - 5% of the total.) Two ANOVA's were conducted on each set of data, one with subjects, the other with items, as the random variable. Subsequently, planned comparison correlated t-tests were performed on related vs. unrelated means for sentence type (active vs. passive matrix clause) crossed with referent (distant vs. recent).

For Exp. 2b, in which the point of the probe was 500 msec. downstream from the initial point, neither ANOVA revealed any significant effects or interactions (p > .1 in all cases).

Means for the experimental conditions (collapsed across items and subjects) are displayed in Table 6. T-tests performed on these means showed no significant differences between related and unrelated targets in any condition. The apparent priming for the recent referent in sentences containing a passive matrix clause did not reach significance ($t_1(31) = -1.77$, p = .09; $t_2(23) = -1.62$, p = .12). Hence, there is no indication of reactivation of an antecedent for PRO even 500 msec. after the infinitive.
For Exp. 2c, in which the probe point was 1000 msec. after the original probe, analyses of variance showed a significant main effect of target type (i.e. related vs. unrelated) (F₁(1,24) = 15.07, p = .0007; F₂(1,16) = 13.22, p = .002). No other effects or interactions were significant.

Means for related and unrelated targets for sentence type and referent are shown in Table 7. T-tests on these means show significant priming for the recent referent in both sentence types (active: t₁(31) = -2.04, p = .05; t₂(23) = -2.07, p = .05; passive: t₁(31) = -3.07, p = .004; t₂(23) = -2.82, p = .01). Priming for the distant filler did not reach significance in either active sentences (t₁(31) = -1.97, p = .06; t₂(23) = -1.41, p = .17) or passive sentences (t₁(31) = -1.05, p = .29; t₂(23) = -1.17, p = .27).

These results suggest that control information is not used to restrict reactivation of prior referents; the recent referent is reactivated both when it is the appropriate antecedent (in active matrix clause sentences), and when it is not (in passive matrix clause sentences). Note that, except for the fact that it occurs a full second after the point where PRO would be represented in the structure, this pattern of reactivation is compatible with FCR's Most
Recent Filler Strategy. It is equally compatible, however, with a backward search process, in which, once the presence of the empty subject is determined, prior NP's are activated right-to-left. The latter hypothesis suggests that probing further downstream ought to reveal priming for the distant filler.

Results of Exp.s 2d and 2e support the backward search hypothesis. Relevant means for Exp. 2d--in which the point of the probe occurred 1200 msec. after the first point--are displayed in Table 8. Analyses revealed a significant effect of target \(F_1(1,24) = 29.21, p = .0001; \ F_2(1,16) = 22.95, p = .0002\). The referent x target interaction was significant in the subjects, but not items, analysis \(F_1(1,24) = 5.43, p = .02, \) but \(F_2(1,16) = 3.10, p = .09\). Likewise for the interaction between sentence type, referent, and target \(F_1(1,24) = 5.07, p = .03; \ F_2(1,16) = 2.17, p = .16\). These effects indicate differential priming of the two referents within each sentence type. Correlated t-tests on these means revealed significant priming for the recent referent in active sentences \(t_1(31) = -4.13, p = .001; \ t_2(23) = -3.50, p = .002\), but for the distant referent in passive sentences \(t_1(31) = -2.00, p = .05; \ t_2(23) = -2.16, p = .04\). It appears, then, that 1200 msec. after the initial probe point, the correct--and only the correct--antecedents of PRO are significantly primed.

Insert Table 8 about here

Finally, analyses of variance for Exp. 2e showed a significant interaction of sentence type with referent, but only with
subjects as a random factor (F₁(1,24) = 7.18, p = .01; F₂(1,16) = 1.86, p = .19). No other effects or interactions were found to be reliable. Means for the relevant experimental conditions are given in Table 9. Correlated t-tests on these means showed significant priming of the distant referent in both sentence types (for active sentences: t₁(31) = -2.12, p = .04; t₂(23) = -2.22, p = .04; for passive sentences: t₁ = -2.46, p = .02; t₂ = -2.04, p = .05).

Here, 1500 msec. after the initial probe point, and just 300 msec. after only the actual antecedents for PRO are activated, only the distant referent is significantly primed.

Insert Table 9 about here

DISCUSSION

The pattern of priming for the experimental sentences in Experiment 2 is summarized below (again, figures given indicate magnitude of priming for the distant filler (DF), "actress", and the recent filler (RF), "dentist", at the five probe points, and figures for the correct antecedent of PRO are shown in italics).

1) The actress invited the dentist...

PRO₁ to # go to the pa#rty at the # mayor's # house #.

<table>
<thead>
<tr>
<th></th>
<th>21</th>
<th>0</th>
<th>28</th>
<th>24</th>
<th>31*</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF:</td>
<td>-10</td>
<td>15</td>
<td>37*</td>
<td>77*</td>
<td>6</td>
</tr>
</tbody>
</table>

- 38 -
2) The actress₁ was invited by the dentist... PRO₁ to go to the party at the mayor's house.

| DF: | 19 | -8 | 29 | 32* | 40* |
| RF: | 19 | 31 | 48* | 2 | -3 |

The lack of significant priming for the first two probe points is clear evidence that PRO does not cause immediate reactivation of its antecedent. This result replicates Experiment 1. The last three probe points show activation of the recent referent followed by activation of the distant referent, suggesting a right-to-left backward search through the string. The time course of this backward search varies between sentence types. In active matrix clause sentences, the recent referent is activated at the third and fourth probe points (2c and 2d), but not at the fifth point (2e), where only the distant referent is activated. In sentences containing a passive matrix clause, on the other hand, the recent referent is active only at point 2c; at the fourth point, the distant referent becomes activated and continues to be active at the fifth point. The difference is at the fourth point, which shows earlier reactivation for the distant referent when the matrix clause is passive rather than active. This may be explained by the following. Passive constructions are analyzed (at least within the Government Binding framework, Chomsky, 1981) as containing a trace following the verb "invite". If the backward search process involves a consideration of all NP's, overt and empty, then this trace--and, apparently, its antecedent--will be taken into account.⁹

1.4 GENERAL DISCUSSION
Experiment 1 was designed to test the on-line realization of the MRFS in relative clause constructions containing PRO. FCR hypothesized that the MRFS, like other parsing strategies, provides the parser with a way of processing ambiguity that may arise if certain components of the grammar, such as constraints on control, are inaccessible to the parser during the initial construction of a parse tree. On the FRC view, the absence of information concerning the antecedent for PRO is dealt with by application of the MRFS, which links PRO to the "most recent potential filler".

We have argued that a strategy such as the MRFS is unnecessary for parsing sentences containing PRO. While we agree with FCR's argument that information such as control information may not be available to the parser (which, on our view, performs only phrase-structure analysis), we disagree that coreference is assigned in the absence of control information, since determining the antecedent of PRO has no bearing on subsequent syntactic analysis.

The results of Experiment 1 support our view. In relative clause constructions similar to those used in the FCR study, there is no evidence for the reactivation of the most recent filler just after the point at which PRO would be represented in the string, nor several syllables after this point. This was the pattern even when the recent referent was the correct antecedent of PRO. In sum, the results of Experiment 1: 1) support the hypothesis that control information is not immediately available during parsing; but 2) refute the hypothesis that a strategy such as the MRFS links PRO with the most recent referent.
Why FRC obtained the results they did is not immediately obvious to us. Recall that they found that "recent filler sentences" (such as "Everyone liked the woman who the little child begged PRO_j to sing those songs for t_j") were easier to process than "distant filler sentences" (such as "Everyone liked the woman who the little child begged t_1 PRO_1 to sing those songs"). A possible explanation for this finding is that the stranded preposition (e.g. "...those songs for...") in the recent filler sentences facilitated comprehension of this type of sentence. Since the final interpretation of a sentence involves determining the roles played by various NP's, unambiguous cues concerning role assignment ought to make processing easier. The presence of the stranded preposition in recent filler sentences makes it immediately clear what the role of "the woman" is; the absence of this preposition, which cannot be registered until the end of the sentence, is not likely to have the same impact. If this account is correct, then recent filler sentences that do not contain stranded prepositions should be no easier to understand than their distant filler counterparts. For example, the recent filler sentence, "Everyone liked the woman who the man chose PRO_j to contact t_j" ought to be no easier to process than the distant filler sentence, "Everyone liked the woman who the man chose t_1 PRO_1 to contact the president". Whether or not this explanation actually proves correct is an empirical question. For other possibilities, see Fodor (1988).

Results of Experiment 1 also replicate findings by Swinney, et al. (also those reported by Tanenhaus, Carlson, and Seidenberg (1985), and Garnsey, Tanenhaus, and Chapman, 1988) that traces in
relative clause sentences do reactivate their antecedents, and do so immediately. This has implications for the types of information that are necessarily available to the parser during sentence processing. At the very least, the parser must be sensitive to verb subcategorization information.

Recall that the follow-up study to Exp. 1a, in which two sets of apparently intransitive verbs were contrasted, showed that a trace was postulated only following a verb that subcategorized for a noun phrase. It appears, then, that prior to postulating a trace after a verb, the parser first determines whether or not the verb takes a NP complement. If the verb does subcategorize for a NP, a trace is posited. If not, no trace is postulated. This might lead one to suppose that knowledge of subcategorization information is all that is necessary for trace postulation. It could quite simply be the case that if a verb subcategorizes for a NP complement, and there is no overt NP in complement position, then the parser posits a trace. There are two problems with this analysis. 1) Many verbs are ambiguous with respect to the types of complement they take, and subcategorize for both a NP complement, and, for example, no complement. In such instances, the parser is faced with either representing a trace or not. One might propose some guiding principle, such as "verbs prefer to be transitive", hence, a trace will be posited after all verbs that are ambiguously transitive/intransitive. In structures such as relative clauses, wh-questions, and passives, a trace postulated after an ambiguous verb will as often turn out to be incorrect as correct. In most other constructions, however, such as in simple declarative sentences, a
trace postulated after an ambiguous verb will always be in error (as in "John ate t"). On the other hand, a principle that states the reverse, that "verbs prefer to be intransitive", would result in the postulation of a trace only after an unambiguously transitive verb. This would circumvent the problem caused by the overgeneration of traces. However, this account conflicts with the results of our follow-up experiment, for it incorrectly predicts that there should be no evidence for trace postulation following any of our "intransitive" verbs. 2) The hypothesis that trace postulation is induced by the co-occurrence of a verb that subcategorizes for a NP complement and the absence of an overt NP in complement position is inconsistent with results of experiments by Crain and Fodor (1985) and Stowe (1986). Their experiments show that in "wh- clauses", there is the expectation of a trace in object position. They found using a self-paced reading task, that reading times increase at the object position in a wh-clause in cases where there is an overt NP in that position rather than a trace. So, for example, in Stowe's study, reading times were elevated (compared to reading latencies for the same item in a non-wh-sentences) at the word "us" in the following: "My brother wanted to know who Ruth will bring us home to t at Christmas." This suggests that the parser expects to posit a trace following a verb that subcategorizes for a NP, and that the presence of the overt NP "us" gives rise to elevated reading times. It would appear, then, that there is another source of information guiding the postulation of traces.

This information has to do with the significance of "argument" vs. "non-argument" positions, and the properties of
relative pronouns. These notions will be discussed here within a GB framework (Chomsky, 1981); however, the general ideas readily translate to other theories, hence slightly different analyses of the syntactic constructions used do not jeopardize our conclusions. The analysis for relative clauses is as follows. The actual antecedent of the trace is the relative pronoun "that" (as in, "That's the actress that the dentist invited..."). This pronoun occurs in a non-argument position, that is, in a position where it cannot receive a thematic role directly from the verb. Its trace, however, is in an argument position, and is assigned a thematic role by the verb which precedes it, or more specifically, "governs" it. Since the relative pronoun is coindexed with the trace, it inherits the thematic role assigned to the trace. It is not obvious what it is about these constructions that serves to cue the parser to expect a trace, whether it is simply the presence of the relative pronoun "that" or "who", or the sequence "...NP that NP..." (as in "That's the actress that the dentist..."), or whether the parser is able to compute which structural positions are argument positions and which are not. We suspect that the mere presence of a relative pronoun is not what triggers the expectation that a trace will appear downstream. First, in certain relative clause constructions, this pronoun may be deleted, as in "That's the actress the dentist invited...". To our knowledge such sentences have not been used in the crucial experiments, so we can only guess that the Crain and Fodor results would be replicated in such structures. Second, and more importantly, relative pronouns may be coindexed with either a trace in object position, as our examples throughout have illustrated, or a trace in subject position, as in "That's the actress who1 t1 invited
the dentist...". In both types of relative clauses, the trace appears in an argument position, that is, in a position where it can receive a thematic role (the trace in subject position being assigned a thematic role by the VP.) In order to correctly postulate a trace, the parser must be endowed both with the knowledge that traces appear in argument positions only, and the knowledge about which positions are argument positions. Underlying such claims, of course, is the assumption that the parser does indeed operate in accordance with this information. Evidence for this assumption is provided by Stowe, whose experiments included sentences containing subject relative clauses, such as, "My brother wanted to know who trace will bring us home...". Reading times for "us" did not show the increases that were found for "us" in the object relative clauses described above. This demonstrates that in the object relatives--but not the subject relatives, in which a trace has already been postulated in subject position--there was the expectation of a trace rather than an overt NP in object position.

To sum up the discussion thus far: the finding that trace (in relative clauses) triggers reactivation of its antecedent, yet PRO does not, implies that the parser has available to it certain types of information but not others. Results show that the parser is able to use information about subcategorization, and argument and non-argument positions within a configuration. In contrast, PRO does not cause immediate reactivation of its antecedent, hence control information is not accessible to the parser on-line.

There is more to this account. The line of reasoning above has to do primarily with the types of information available to the
parser, which, as a structure-building device, ought to have access to structural information only. Notice, though, that our conclusions are based on evidence from semantic priming, from patterns of activation assessed by our semantic priming task. We do not wish to imply that the parser is directly involved with accessing the semantic properties of lexical items. We do believe, though, that the parser provides information to a device that does have access to lexical semantics. Suppose that there is a processing module responsible for determining coreference of an antecedent and a referentially-dependent item such as a trace or PRO (see Nicol, 1988, for an extensive discussion of coreference processing) and that this device receives input from the parser. So, for example, once the parser has represented a trace in the parse tree, the coreference device recognizes the trace as an item that refers to a previously mentioned NP, and reactivates that NP.

Consider again the differences between the pattern of reactivation for trace and PRO: immediate reactivation of the correct antecedent for trace; delayed reactivation of all previously mentioned referents for PRO. Suppose that this coreference module reactivates all and only those prior NP’s that are in the appropriate structural position to act as an antecedent. In the relative clause constructions used in our experiments, there is only one NP that could possibly be the antecedent of trace. Hence, once a trace is represented after the verb, there is immediate reactivation of that antecedent. On the other hand, the antecedent for PRO requires a certain amount of computation. Notice that there is not a unique structural position within the configuration of a sentence with which
the antecedent of PRO is associated. For example, in the sentence
"John verb Bill PRO to go", either NP could be the antecedent. While
it is usually the object NP that is coindexed with PRO, there are
exceptions, such as in sentences containing the verb "promise", for
which the subject of the verb is the antecedent of PRO. And there
are exceptions to the exceptions, as in, "John promised Bill PRO to
be allowed to go", in which the object of the verb is the antecedent.
Contributing to the unpredictability of the structural position of
the antecedent of PRO is the existence of rationale clauses and
purpose clauses. Consider the following: "John hired Bill PRO to
placate Susan"; "John hired Bill PRO to look after Susan". The
first contains a rationale clause, which generally describes the
reason for the action depicted by the matrix clause, i.e. John hired
Bill in order to placate Susan. Here, PRO is coindexed with John.
Purpose clauses, on the other hand, normally describe the function to
be carried out the the object of the matrix clause; in the second
sentence, Bill was hired for the purpose of looking after Susan. In
this instance, PRO is coindexed with Bill. Furthermore, PRO can have
an "arbitrary", unspecified antecedent, as in-"It is a good idea PRO
to stay indoors in this weather", where the antecedent (presumably,
"one", or "everyone") is merely implied. Thus, not only is it the
case that the antecedent of PRO is not syntactically determined, even
control information, which dictates which NP controls PRO given a
particular verb, and ought to be readily accessible, may be
unreliable in determining the antecedent of PRO. Since identifying a
unique antecedent for PRO appears to require knowledge about much
more than syntactic structure, it is likely that this is achieved by
higher level, inferential processes. Our account of the pattern of
activation in response to PRO is that, once recognized (and this may take time), PRO triggers reactivation of *all possible antecedents*. Presumably, higher level processes, which may have access to a wide range of knowledge sources, select only the most appropriate of these candidates.

To conclude, the studies reported here provide evidence for the following claims. 1) The parser has access to only structural information to perform syntactic analysis. So, for example, to determine at what point to postulate a trace, the parser uses information relating to both verb subcategorization and argument/non-argument positions within a tree. 2) There is a device that exploits information provided by the parser to reactivate a "candidate set" of antecedents; it reactivates all and only those previously-mentioned referents that bear the appropriate syntactic relationship to the referentially-dependent element. The initial candidate set is restricted only by structural information, with other types of information acting to select from this set the most appropriate antecedent.
1. Note that PRO has a strict distribution, occurring before infinitives and gerunds, not before tensed verbs. It would not be legitimate, therefore, to analyze the embedded clause in the sentence given in the preceding paragraph ("While Mary was mending the socks fell...") as containing an empty subject. If the NP, "the socks" is taken to be the complement of the matrix verb phrase, rather than the subject of the embedded clause, then the tensed verb, "fell" actually has a missing subject, and the entire string requires reanalysis.

2. We wish to point out another way of characterizing the ambiguity such structures present. While it is true that the empty subject in these sentences may refer to either referent, we do not consider the ambiguity to center on the identity of PRO, but rather on the structural properties of the verb. Verbs such as "beg" subcategorize for either "NP + infinitival sentence", or simply "infinitival sentence". Once a subcategorization frame is selected, the antecedent for PRO clearly follows: in both cases, PRO is coindexed with the closest preceding NP. Hence, in (1a), in which the complement of "beg" is the simple infinitival clause, PRO is coindexed with the subject of the embedded relative, i.e. "the little child". In (1b), where the argument of "beg" is "NP + infinitive", PRO is coindexed with the object of the embedded verb, "beg", which in this case, happens to be phonologically empty, but linked to "the woman".

3. It should be noted that this phenomenon relates to object gaps which have quite different properties from subject gaps, and are likely to exhibit different processing characteristics. (Chomsky, 1981, Berwick and Weinberg, 1984).

4. It is not at all clear to us why one would expect the adult parser to mimic children's final interpretations of sentences. To the extent that children do use strategies to interpret sentence, one would expect these to drop out of use as the child's grammar approaches that of the adult.

5. More accurately, the antecedent of the trace is the relative pronoun, "that", which is coindexed with the head of the relative clause, "the boy". We assume that the semantic features of the head are acquired by the relative pronoun, so that the reactivation of the relative pronoun that is triggered by the presence of the trace involves reactivation of the semantics of the head.

6. Note that in the "distant filler" sentences (1b, 2b), there is a trace following beg/force which is coindexed with PRO:

1b) Everyone liked the woman\textsubscript{i} who\textsubscript{i} the little child begged t\textsubscript{i} PRO\textsubscript{i} to sing those songs.

2b) Everyone liked the woman\textsubscript{i} who\textsubscript{i} the little child forced t\textsubscript{i} PRO\textsubscript{i} to sing those songs.

In these sentences, PRO is coindexed with the most recent NP, the trace, which is identified with the NP, "the woman" (via the relative pronoun, "who"). If empty categories qualify as "potential fillers", then the MRFS will coindex PRO with trace, which is the correct
interpretation. Since this runs counter to the predictions made by FRC, one can only assume that the term "potential filler" applies only to lexically specified NP's, not to empty categories.

7. In a sense, the introduction of these intervening phrases prevent us from testing the MRFS, or at least one version of it. Since all such phrases contain NP's, as in "...from the new medical center...", one might construe the most recent filler to be "the new medical center". However, this construal seems at odds with what the MRFS was meant to account for, which is that certain constructions are harder to understand. If PRO is misconstrued in these constructions, surely the interpretation has to do with identifying PRO with "the dentist", not with "the new medical center".

8. For methodological reasons, we ran the downstream study before the upstream study: the cross-modal program we used allowed us to request a delay following the 1000 Hz. signal that triggered the CRT display of the target word. Obviously, we could not request that targets be displayed prior to the tone. For the upstream condition we were forced to re-record the tones at the new probe point.

9. It is not crucial to the argument whether or not an element such as a trace is actually represented in the string. Other linguistic theories, such as LFC, encode the surface subject of the passive as the object of the verb at a level of representation in which relationships among entities in a string are spelled out. The pattern of reactivation at issue here may just as well reflect this type of representation.
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th></th>
<th></th>
<th></th>
<th>Recent Antecedent</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
<td>Priming</td>
<td>Related Target</td>
<td>Unrelated Target</td>
<td>Priming</td>
<td></td>
</tr>
<tr>
<td>Transitive Verb Ending</td>
<td>720</td>
<td>795</td>
<td>75 *</td>
<td>749</td>
<td>753</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Intransitive Verb Ending</td>
<td>702</td>
<td>773</td>
<td>71 *</td>
<td>732</td>
<td>768</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 1a. Values for the correct antecedent of PRO in a given condition are presented in italics.

* p < .05 (for both subjects analysis and items analysis)
<table>
<thead>
<tr>
<th>Distant Antecedent</th>
<th></th>
<th></th>
<th>Recent Antecedent</th>
<th></th>
<th></th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related</td>
<td>Unrelated</td>
<td>Priming</td>
<td>Related</td>
<td>Unrelated</td>
<td>Priming</td>
</tr>
<tr>
<td>Transitive</td>
<td>666</td>
<td>696</td>
<td>30</td>
<td>652</td>
<td>658</td>
<td>6</td>
</tr>
<tr>
<td>Verb Ending</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intransitive</td>
<td>680</td>
<td>692</td>
<td>12</td>
<td>657</td>
<td>685</td>
<td>28</td>
</tr>
<tr>
<td>Verb Ending</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 1b: Upstream probe point. Values for the correct antecedent in a given condition are presented in italics.
<table>
<thead>
<tr>
<th></th>
<th>Related Target</th>
<th>Unrelated Target</th>
<th>Priming</th>
<th>Related Target</th>
<th>Unrelated Target</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transitive</strong></td>
<td>765</td>
<td>822</td>
<td>57 *</td>
<td>777</td>
<td>789</td>
<td>12</td>
</tr>
<tr>
<td><strong>Verb Ending</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intransitive</strong></td>
<td>774</td>
<td>822</td>
<td>48</td>
<td>794</td>
<td>815</td>
<td>21</td>
</tr>
<tr>
<td><strong>Verb Ending</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Mean response latencies (in msec) to targets in different treatment conditions, Exp. lc: Probe point 300 msec. downstream from original point. Values for the correct antecedent in a given condition are presented in italics.

* * p < .05 (for both subjects and items analysis)
<table>
<thead>
<tr>
<th>Distant Antecedent</th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related Target</td>
<td>Unrelated Target</td>
</tr>
<tr>
<td>&quot;Pure Intransitive&quot;</td>
<td>699</td>
</tr>
<tr>
<td>Verb Ending</td>
<td></td>
</tr>
<tr>
<td>&quot;Transitive&quot;</td>
<td>705</td>
</tr>
<tr>
<td>Verb Ending</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Mean response latencies (in msec) to targets in different treatment conditions for subgroups of "Intransitive" verbs, Exp. 1a. Values for the correct antecedent in a given condition are presented in italics.
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th></th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
<td>Priming</td>
</tr>
<tr>
<td>Active Matrix</td>
<td>630</td>
<td>651</td>
<td>21</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive Matrix</td>
<td>645</td>
<td>664</td>
<td>19</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 2a. Values for the correct antecedent in a given condition are presented in italics.
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
</tr>
<tr>
<td>Active Matrix</td>
<td>647</td>
<td>647</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive Matrix</td>
<td>627</td>
<td>619</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>618</td>
<td>633</td>
</tr>
<tr>
<td></td>
<td>616</td>
<td>647</td>
</tr>
</tbody>
</table>

Table 6. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 2b: Probe point 500 msec. after original point. Values for the correct antecedent of PRO are given in italics.
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th></th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
<td>Priming</td>
</tr>
<tr>
<td>Active Matrix</td>
<td>611</td>
<td>639</td>
<td>28</td>
</tr>
<tr>
<td>Passive Matrix</td>
<td>625</td>
<td>654</td>
<td>29</td>
</tr>
</tbody>
</table>

Table 7. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 2c: Probe point 1000 msec. downstream from initial point. Values for the correct antecedent in a given condition are presented in italics.

* p < .05, ** p < .01 (for both subjects and items analyses.)
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
</tr>
<tr>
<td>Active Matrix Clause</td>
<td>658</td>
<td>682</td>
</tr>
<tr>
<td>Passive Matrix Clause</td>
<td>632</td>
<td>664</td>
</tr>
<tr>
<td></td>
<td>614</td>
<td>691</td>
</tr>
<tr>
<td></td>
<td>666</td>
<td>668</td>
</tr>
</tbody>
</table>

Table 8. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 2d: probe point 1200 msec. downstream from initial point. Values for the correct antecedent in a given condition are presented in italics.

* p < .05, ** p < .01 (for both subjects and items analyses.)
<table>
<thead>
<tr>
<th></th>
<th>Distant Antecedent</th>
<th></th>
<th>Recent Antecedent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
<td>Priming</td>
</tr>
<tr>
<td>Active Matrix</td>
<td>548</td>
<td>579</td>
<td>31 *</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive Matrix</td>
<td>544</td>
<td>580</td>
<td>36 *</td>
</tr>
<tr>
<td>Clause</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Mean response latencies (in msec) to targets in different treatment conditions, Exp. 2e: Probe 1500 msec. downstream from original point. Values for the correct antecedent in a given condition are presented in italics.

* p < .05 in both subjects and items analyses.
CHAPTER 2: DETERMINING THE ANTECEDENT OF PRONOUNS AND REFLEXIVES: MECHANISMS AND CONSTRAINTS
2.1 INTRODUCTION.

This paper examines the mechanisms involved in the assignment of an antecedent to an overt anaphoric element, such as a pronoun. In general, pronouns are used to reintroduce a previously-mentioned referent into a sentence or discourse without repetition of the referent itself. But often there is more than one prior referent to which the pronoun may refer, as in (1):

1) Mary told Sue that Mavis would introduce her to the celebrity.

In this sentence, the pronoun, "her" could equally well refer to either "Mary" or "Sue".

Much of the past research in this area has explored the variables that appear to play a role in resolving the ambiguity of reference in sentences such as (1), which contains multiple candidate antecedents. Such variables include the following. The semantic context in which referents appear is obviously relevant to selecting an antecedent. Hirst and Brill (1980) correlated strength of contextual bias of a lead-in sentence (predetermined by pilot testing) with choice of antecedent and with response latencies to determine the antecedent. Grober, Beardsley, and Caramazza (1978) suggest that resolution may be driven by a parallel function strategy, so that in sentence (1) above, the object of the matrix verb, "Sue", would be more likely to be interpreted as the actual antecedent of the object pronoun, "her". The semantic properties of the matrix verb--specifically, "implicit causality"--may also influence selection (Garvey, Caramazza, and Yates, 1976). For instance, in dual-clause sentences containing a verb such as
"punish", the object of the verb tends to corefer to the pronoun (e.g. "Mary punished Sue because she..."), whereas the subject of a verb such as "anger" is the more plausible antecedent (e.g. "Mary angered Sue because she...").

While it is important to our understanding of coreference operations to isolate those factors which affect the ultimate interpretation of a pronoun, the research reported in this paper has as its focus a prior stage of processing: the mechanisms by which potential antecedents are identified, and the types of information available to such mechanisms.

This assumes that coreference processing consists of two stages: one in which referents are identified as possible antecedents of a pronoun, and another, in which a particular referent is selected. The empirical evidence that supports this assumption comes from research conducted by Corbett and Chang (1983), and Cowart and Cairns (1987). The details of their studies are given below.

Corbett and Chang (1983) suggest that a pronoun serves as a cue to retrieve previously-mentioned referents from memory. They constructed two-clause sentences in which there were two potential antecedents in the first clause and a subject pronoun in the second, e.g. "Karen poured a drink for Emily and then she put the bottle down." A probe recognition task was used: subjects were to indicate whether or not a probe word presented at the end of the sentence had appeared in the sentence they had just read. Response times to each of the referents were recorded and RT's for a given referent (either the antecedent or nonantecedent) were compared cross two types of
sentences, those containing a pronoun and those containing instead a repetition of the subject of the first clause. For example, response times to "Karen" and "Emily" following the sentence given above were compared to reaction times to these probes following the non-pronoun control sentence, "Karen poured a drink for Emily and then Karen put the bottle down.". Reaction times for the nonantecedent, "Emily" were significantly faster following the pronoun sentence as compared with the nonpronoun sentence. Corbett and Chang interpret this result as indicating that both potential antecedents are retrieved in response to the appearance of the pronoun.

Cowart and Cairns (1987) provide further support for a two-stage coreference process. They propose a model in which the initial antecedent assignments may then be revised by later processes. Specifically, they hypothesize that the mechanisms at one stage are sensitive only to information concerning phrase structure and syntactic constraints on coreference; at the next stage, the coreference mechanisms have access to any information that is relevant to establishing coreference.

Cowart and Cairns examine the effect induced by the occurrence of a pronoun in a preposed clause on the syntactic analysis of an ambiguous expression. Consider the following pair of sentences: "While they usually come with several internal partitions, packing cases..."; "While the boxes usually come with several internal partitions, packing cases...". The term, "packing cases" is structurally ambiguous, since "packing" may be either a gerundive nominal or an adjective. Sentences of this type were presented to subjects auditorily. Following the ambiguous
expression, the word "is" or "are" was presented tachistoscopically, and subjects were asked to read the word aloud. Note that when the ambiguous term is construed as a gerund, the expression, "packing cases" requires the singular verb, "is" (as in, "packing cases is an unpleasant task"); however, when this item is analyzed as an adjective, the following verb must be plural, to agree with the plural noun, "cases". Response latencies for each target were compared across sentence types. Results indicate that response times to "is" were longer in the pronoun condition. Cowart and Cairns interpret this result as demonstrating that the presence of the pronoun, "they" in the first clause invokes a mechanism that will provide it with an antecedent. Since the term, "cases" is structurally appropriate as an antecedent on the adjective + noun reading of the ambiguous expression, this syntactic analysis is selected. Hence, a plural verb is expected to follow, and this expectation produces comparatively longer naming times on the singular verb, "is". A second study shows that this phenomenon, which they call the "Pronoun Bias Effect", is present even when coreference between the pronoun and the following noun results in a semantically anomolous sentence, such as "Even though they eat very little oil, frying eggs...". However, the effect vanishes in cases where coreference would create a syntactically anomolous sentence, such as, "If they want to believe that visiting uncles...". This finding suggests that syntax, but not semantics, constrains the initial assignment of an antecedent.

Consider these two sets of findings together. The Corbett and Chang finding of retrieval of multiple referents suggests that at
the first stage of coreference processing, pragmatic information cannot be used to select a previously-mentioned referent as the most appropriate antecedent of a pronoun. Cowart and Cairns show that the initial assignment of an antecedent to a pronoun obeys structural constraints, but not constraints on semantic or pragmatic well-formedness. The picture that emerges is one in which, at an early stage of processing, a pronoun triggers all and only those prior referents that are structurally appropriate as the antecedent.

This model predicts that in sentences such as (1) (presented again below), both referents in the matrix clause will be reactivated.

1) Mary told Sue that Mavis would introduce her to the celebrity.

Hence, both "Mary" and "Sue" ought to be re-accessed in response to the pronoun, "her". Experiment 1 was conducted to test this prediction.

2.2 EXPERIMENT 1.

A crucial aspect of the model under consideration is that a referent will be reactivated only if coreference with the pronoun does not violate syntactic constraints on coreference. Therefore, it is important to test not only the first two referents in a sentence such as (1), but also the third referent, the subject of clause in which the pronoun appears, since this referent cannot be the antecedent. Hence, as in sentence (1) above, test sentences included three referents prior to the pronoun, as in (2):

2) The landlord told the janitor that the fireman with the gas-mask
would protect him if it became necessary.

In sentences such as (2), "him" may refer to either of the referents in the matrix clause, but cannot refer to the subject of the clause in which the pronoun appears, in this case, "fireman".

Now consider (3), which contains a reflexive in place of the pronoun:

3) The landlord told the janitor that the fireman with the gas-mask would protect himself if it became necessary.

In contrast to (2), the only possible antecedent of the anaphoric element, "himself" is the subject of the embedded clause. This difference between pronouns and reflexives with respect to their coreference possibilities is captured by formal theories of syntax, such as Government and Binding (Chomsky, 1981). Binding theory expresses constraints on coreference as follows:¹

4) a. A reflexive must be bound (i.e. corefer to an antecedent) in a "local" domain.

b. A pronoun must be free in a "local" domain.

The first condition, Condition A, states that a reflexive must refer to a noun phrase that is within the same clause, and in a particular structural relation to it. Thus, in a sentence such as (3), "himself" refers to the subject of the clause, the fireman.

Condition B states that a pronoun must not refer to an element in this position; a pronoun is free to refer to any noun phrase outside this domain. Thus, in (2), the pronoun, "him" may refer to either "landlord" or "janitor".

Since the referents that constitute potential antecedents in (2) vs. (3) are in complementary distribution, testing reactivation patterns of referents in sentences such as (3) as well as (2) provides an interesting contrast: the referents for which priming is
predicted in one case are just those referents for which priming is not expected in the other. Therefore, reactivation of referents is examined in both these sentence types.

The methodology employed in this experiment (and the experiments which follow) is the cross-modal priming technique. This is a dual-task paradigm which, in this experiment, involves having subjects listen to sentences and make lexical decisions to visually-presented word/nonword targets. This technique has been shown to be reliably sensitive to the activation of word meanings (e.g. Swinney, 1975). Further, it has the advantage of providing on-line measures of activation: permitting one to probe for activation at relevant points within the sentence, such as immediately following a pronoun.

METHODS

Subjects.

Sixty-one subjects participated in this study. The majority consisted of University of Arizona undergraduates who participated for course credit. The rest were each paid $5 for their participation.

Materials and Procedure.

Twenty-four pairs of sentences were constructed. Sentences were identical except for the anaphoric element, as in (2) and (3) above. All sentences contained three referents of the same gender; eighteen sentences containing all male referents, and six containing all female referents.² (All materials are presented in Appendix 2.)
Sentence construction was constrained by a number of factors. First, the methodology that was used--the cross-modal priming technique--involves lexical decisions to items that are related to the prime; therefore referents must be "primable", i.e. referents must have associates. So, for example, to test for the activation of "landlord", a target such as "rent" would be presented. Second, the referent in subject position of the embedded clause had to be sufficiently distant from the pronoun that any finding of activation following the pronoun would unequivocally signal the re-activation of this referent, rather than residual activation, hence a modifying phrase intervened between the subject and the pronoun.

Seventy-two filler sentences were also created. Twelve of these--the "pseudo-experimental" sentences--had exactly the same structure and format as the experimental sentences. The rest were roughly equivalent to the experimental sentences in terms of length, complexity, and content. Ten of these were used as practice items. Experimental items were interspersed among the filler sentences in such a way that no two experimental sentences were contiguous. In all, there were ninety-six sentences.

In addition, six presentation lists were constructed: these lists contained target items on which subjects were to make a lexical decision. Each experimental sentence had associated with it six target words: three of these were associates of the three referents, and three were control words for the associates (matched in length and frequency). The experiment was designed with target type (i.e. semantically related vs. unrelated) as a within-subjects factor, but with referent as a between-subjects factor. So, for example, with
respect to Referent 1 (the first-mentioned referent), the related
targets and unrelated controls were counter-balanced across two lists
such that each list contained twelve of each type of target.
Sentence (2) and its six targets are shown below. Targets for the
pseudo-experimental sentences were always non-words; this was to
ensure that a particular sentence type would not always be associated
with a particular response to a target. Each filler sentence had
either a real word target or nonword target associated with it.

2) The landlord (Ref. 1) told the janitor (Ref. 2) that the fireman (Ref. 3)
   RENT               CLEAN               SMOKE
   herd               score               shift

   with the gas-mask would protect him from getting hurt.

The sentences were recorded by a female speaker reading at a
normal rate of speech. All sentences (experimental and filler) were
digitized at a sampling frequency of 16K. A wave-form editing
system was used to "splice" the pronoun and reflexive versions of the
experimental sentences such that each version was identical up to the
point of the anaphoric item. During this editing process, the point
in each sentence at which a probe was to appear was identified and
labelled. (These labels were then converted to 800 Hz. pulses.) In
the experimental and pseudo-experimental sentences, the probe point
was at the offset of the anaphoric item; in fillers, the probe point
varied randomly. The sentences and pulses were then recorded onto
audio tape; the sentences were recorded onto the right channel, the
pulses onto the left. Two separate tapes were made. The
experimental sentences were counterbalanced across tapes so that each
tape contained equal numbers of sentences containing pronouns and
sentences containing reflexives.
Sentences were presented auditorily through head phones. Subjects heard only the right track of the audio tape. The left track, which contained only pulses, was connected to a voice trigger, which signalled an IBM computer to display the appropriate target (for 300 msec.) on a CRT screen that was positioned in front of each subject, and to start a timer. To maintain the subject's attention on the appropriate area of the screen, two vertical lines flanked the point on the screen at which targets were displayed. These remained on the screen throughout the experiment. Subjects made a lexical decision to the item, and pressed the appropriately labelled button in front of them. The button press stopped the timer. To prevent subjects from attending only to the lexical decision task, subjects were told at the outset that after some portion of the sentences, they would hear a bell, and that at the sound of the bell, they were to write down everything they could remember about the sentence they had heard immediately prior to the bell. Since this task was included only as a way of encouraging subjects to attend to the sentences, the paraphrases obtained from the subjects were not analyzed.

RESULTS

Data obtained from subjects whose mean real-word response time was greater than 1000 msec. were excluded from further analysis.

Two analyses of variance were performed: the first treated subjects as a random factor (F1); the second treated items as a random factor (F2). There was a significant main effect of target (related vs. unrelated) in only the subjects analysis (F1(1,58) -
13.942, p < .0001), and a reliable main effect of referent (1 vs. 2 vs. 3) in only the items analysis ($F_{2}(2,44) = 7.976, p = .001$). Both analyses revealed a significant interaction of type of anaphora (pronoun vs. reflexive) x referent x target ($F_{1}(2,58) = 6.311, p = .003; F_{2}(2,44) = 11.077, p < .0001$). This is the critical interaction: priming is determined by comparing means for related and unrelated targets; this comparison is only meaningful if the levels of referent and the levels of anaphora are maintained. These comparisons are examined below. There were no other significant main effects or interactions.

The mean reaction times derived from this interaction are shown in Table 1. T-tests were performed on the means for related vs. unrelated targets. Consider, first, priming for referents in the pronoun condition. Referents 1 and 2 both showed significant priming (R1: $t_{1}(19) = 2.025, p = .029; t_{2}(23) = 1.884, p = .036; \ R2: t_{1}(19) = 1.927, p = .0345; t_{2}(22) = 1.850, p = .039$). (The $p$ values shown here and throughout are for one-tailed t-tests.) By contrast, referent 3 showed a reverse effect: the mean for related targets was higher than the mean for unrelated targets. This difference was not significant. In the reflexive condition, neither referent 1 or 2 showed significant priming (R1: $t_{1}(19) = .0179, p = .493; t_{2}(23) = .1378, p = .445; \ R2: t_{1}(19) = .964, p = .1735; t_{2}(23) = 5.185, p = .0001$). Referent 3, however, was significantly primed ($t_{1}(19) = 4.369, p < .0001; t_{2}(23) = 5.185, p < .0001$).

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Insert Table 1 about here

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DISCUSSION

- 71 -
As predicted, there was reactivation of all and only those referents for which coreference with an anaphoric element does not violate constraints on binding. Thus, in the pronoun condition, there was reactivation of both referents in the matrix clause, and no reactivation of the subject of the clause containing the pronoun; but in the reflexive condition, there was reactivation of only the subject of the clause containing it. Hence, these results provide support for the hypothesis that the mechanism that reactivates prior referents has access to structural constraints.

The finding of reactivation of multiple referents is also in keeping with the notion that semantic and pragmatic information is not used to constrain reactivation. While it is true that the experimental sentences used here were not pragmatically biased toward a particular referent, the fact that reactivation was immediate suggests that such sources of information are not used at this stage: since it is often the case that a pronoun may be followed by information which provides disambiguating cues, one would expect that a system that is able to use semantics and pragmatics would delay commitment to a particular referent until the end of the relevant clause.

Thus, it appears that there is a stage of processing during which candidate antecedents are reactivated. At this stage, only structural information is available to restrict reactivation. Other types of information which may influence antecedent selection are inaccessible at this level, and only come into play at the next stage of processing.
Unfortunately, these results are compatible with quite a different account of coreference processing. In the sentences containing reflexives, there is a unique antecedent: the subject of the clause in which the reflexive appears. Although this fact may be characterizable in terms of syntactic structure, it may not be a uniquely syntactic phenomenon. Thus, selecting as the antecedent of a reflexive a referent that appears outside the local domain of the referent may also constitute a semantic violation, as in a sentence such as, "John asked Mary to drive himself to work." As for the pronoun cases, there is also a plausible explanation. The finding of reactivation of multiple referents may only be apparent. For any given experimental sentence, and for a given subject participating in the experiment, there is undoubtedly one referent that is the more appropriate as the antecedent of the pronoun. Suppose that only the more appropriate referent is reactivated. If the experimental sentences are truly unbiased, then on the average, referent 1 will be primed half the time, and so will referent 2. This pattern could give the appearance of multiple activation. Experiment 3 provides evidence that semantic information does not play a role. This issue will be raised again during the discussion of that experiment.

While the results of this study point to a mechanism that operates independently of higher level information, it is conceivable that certain types of semantic information may influence reactivation patterns. It is a property of pronouns that they are devoid of semantic content except for specifications of number, gender, and animacy (or, more accurately, humanness). It is also a property of pronouns that they must match their antecedents with respect to these
features. In cases where there is more than one structurally-appropriate candidate antecedent, mismatches in features provide clear disambiguating information, as in the sentence, "Mary told Bill that Mavis would introduce her to the celebrity." (cf. sentence (1)). Given that pronouns contain only these semantic features, and given the obvious usefulness of such features in restricting the initial set of candidate antecedents, it is feasible that this information is available at an early stage of coreference processing.

The following experiments explore the possibility that these pronominal features are used to limit the reactivation of prior referents. In these experiments, referents either differ in number (Experiment 2), or gender (Experiment 3).

2.3 EXPERIMENT 2

In this experiment, the two referents outside the local domain of the pronoun were probed. There are two clear predictions: 1) if information concerning number is used to restrict reactivation of referents, then only the referent that bears the same number specification as the pronoun will be reactivated; 2) if such information is not available to influence reactivation, then both referents should be reactivated. There is a third possibility: the plural pronoun, "them" could refer to both referents, since both referents may, as a unit, serve as the antecedent, as in a sentence such as, "John told the boys that Bill would pick them up after the show", in which "they" could refer to "John and the boys".

METHODS
Subjects.

Fifty subjects participated in this experiment. Again, subjects either participated for course credit, or were paid $5 for their participation.

Materials and Procedure.

The materials are essentially identical to those used in Experiment 1, except for the following changes. Experimental sentences were modified such that referents 1 and 2 differed in plurality. Also, the anaphoric element was either a singular pronoun or a plural pronoun. For example, the modified versions of sentences (2) and (3) are given here as (4) and (5):

4) The landlord told the janitors that the fireman with the gas-mask would protect him from getting hurt.

5) The landlord told the janitors that the fireman with the gas-mask would protect them from getting hurt.

In this experiment, there were four, rather than six, presentation lists: two counterbalanced lists associated with referent 1; two associated with referent 2. Referent 3 was not tested. All target items were identical to those used in Experiment 1.

The procedure was identical to that described in the first experiment.

RESULTS

Again, all data obtained from subjects whose mean for correct responses to real words exceeded 1000 msec. were excluded from analysis. In addition, individual reaction times were omitted if
they were more than two standard deviations away from the subject's mean response time for correct responses to words. 4

Two ANOVA's were conducted, one with subjects (F₁), one with items (F₂) as the random variable. The subjects analysis revealed a significant main effect of target (related vs. unrelated) (F₁(1,49) = 7.205, p = .01). Both subjects and items analysis showed a significant interaction of target x congruence (i.e. referent and target match in number) (F₁(1,49) = 11.791, p = .001; F₂(1,23) = 7.390, p = .012), indicating a difference in priming when the antecedent and pronoun are either congruent or incongruent. There were no other reliable main effects or interactions.

Table 2 presents mean reaction times (in msec.) for the 3-way interaction of target x congruence x pronoun (singular vs. plural). These means were subjected to t-tests to determine priming (i.e. to determine whether the mean for the related target was significantly lower than the mean for the unrelated target). Considering first the congruent cases, priming in the singular pronoun condition was reliable in the subjects analysis only (t₁(49) = 2.158, p = .018; t₂(23) = 1.663, p = .055), as was priming in the plural pronoun condition (t₁(49) = 3.429, p = .0005; t₂(23) = 1.465, p = .075). For the incongruent cases, means for related items were actually slightly higher than for the unrelated targets. These differences were nonsignificant.

________________________________________
Insert Table 2 about here
________________________________________

DISCUSSION
Results of this experiment suggest that reactivation of antecedents is indeed restricted by number information, so that only a referent that matches the pronoun in number is re-accessed. There is no evidence for activation of both antecedents in response to either pronoun, thus the prediction that the plural pronoun could produce activation of both prior antecedents is not supported.

This finding is consistent with the results of the studies by Cowart and Cairns, described above. Recall that the sentences they used all contained a plural pronoun followed by a either a singular or plural expression (e.g. "While they usually come with several internal partitions, packing cases..."). The Pronoun Bias effect that they discovered depends crucially on the fact that the plural pronoun is linked to the plural expression.

The finding that number information appears to be accessible to the coreference mechanisms at the early stage of processing is illuminating with respect to the operations underlying the reactivation of referents. Note that the nonreactivation of a structurally appropriate referent raises an interesting question: how is number information determined prior to reactivation of the referent under consideration? In other words, the mere act of determining a number specification of a referent ought to involve reactivation of the referent itself. But perhaps not. Since number is normally marked by the inflectional suffix (in English), it may be possible to retrieve only the number marker. Then, if it is the case that the number feature does not match that of the pronoun, the referent is not considered further; otherwise, the entire complex of semantic features associated with the referent is reactivated. If
the initial retrieval turns up no marker (as it would in the case of "landlord" above), this would be construed as an indication that the referent is singular, and could be rejected as a possible antecedent.

If this characterization of the mechanisms involved in selective retrieval of referents is accurate, then in the next study, in which referents differ in gender, this particular finding of selective activation ought to be maintained. But only if the following assumptions hold. 1) The suffixes marking gender are stored in the same way as the plural suffix. It is possible that the feminine suffix is not treated the same way as the plural, since these suffixes have quite different properties. For example, the plural inflection is necessary to determine subject-verb agreement, while the gender marking is not involved in agreement relations. In addition, the plural marker is regular and productive; in fact, plural is rarely marked in any other way. For gender, the opposite is true; there are a variety of possible feminine suffixes (e.g. -ess, -ette, -ix, -ina) which are generally non-productive; normally, gender is not marked by a suffix. 2) The absence of marking itself carries a feature value. In the case of singular/plural marking, the absence of a suffix signifies the singular. The equivalent case here, presumably, is that absence of marking would indicate a male referent.

2.4 EXPERIMENT 3.

There are two major predictions for patterns of reactivation in this experiment. 1) If gender information is accessible in that same way as number information, then referents of the same gender as
the pronoun will be reactivated; 2) if such information is not available, then there will be reactivation of both referents.

METHODS

Subjects.

Thirty-nine subjects participated for either course credit or a payment of $5.

Materials and Procedure.

Although the materials were largely identical to those used in Experiments 2, the experimental sentences were revised for this experiment such that the anaphoric element was either a masculine or feminine pronoun. In addition, one referent from each sentence was replaced with a referent of a different gender. Ideally, all the female referents in these sentences would contain a feminine suffix, in order to test the hypothesis that suffixes may be independently activated. However, suffixation of this sort is so uncommon that, obsolete items such as "murderess" aside, only sixteen such referents could be found. The rest tended to be inherently female, such as, "nun". The replacement of one referent with another that differed in gender required revisions in the target lists, and these lists were modified accordingly. Example sentences are shown in (6) and (7).

6) The landlord told the nun that the fireman with the gas-mask would protect him from getting hurt.

7) The landlord told the nun that the fireman with the gas-mask would protect her from getting hurt.

In all other respects, this experiment was identical to Experiment 2.
RESULTS

Prior to analysis, data were treated as for Experiment 2.

Two analyses of variance were conducted, one with subjects (F₁) as the random factor, one with items (F₂) as the random factor. On both analyses, there was a significant effect of target (related vs. unrelated). (F₁(1,38) = 14.440, p = .001; F₂(1,23) = 11.937, p = .002). No other main effects or interactions were significant.

Mean reaction times derived from the three-way interaction of target x congruence x pronoun are presented in Table 3. T-tests performed on these means reveal the following. In the male pronoun condition, congruent referents were significantly primed (t₁(38) = 1.883, p = .034; t₂(23) = 2.094, p = .024), but for incongruent referents, means for related targets were slightly slower than for the unrelated controls. In the female pronoun condition, priming for congruent referents was significant, but only on the subjects analysis (t₁(38) = 2.376, p = .012, t₂(23) = 1.0459, p = .153); whereas priming for incongruent referents was significant on both analyses (t₁(38) = 2.863, p = .004; t₂(23) = 2.356, p = .014).

Insert Table 3 about here

DISCUSSION

The results show that priming in sentences containing a masculine pronoun is selective: only the male referent is reactivated. This suggests that gender information is available to constrain reactivation of referents. The results for the feminine
pronoun sentences, however, indicate that both referents are primed, suggesting that information concerning gender is not used to limit reactivation. Hence, neither prediction is supported. How can this pattern of priming be explained?

This pattern of results may reflect a feature of the referents that were used in this study; the female referents are almost always unambiguously female, whereas the male referents tend to be gender neutral. The majority of the female referents are overtly marked as feminine, such as "hostess", "ballerina", and "policewoman"; those that are not marked in this way tended to be inherently female, such as "bride", and "queen". By contrast, the male referents were generally unmarked. Although a small portion of these referents were inherently male, such as, "king", "butler", and "boy", for the most part, the construal of these referents as male is based on probability. In sentences containing one referent that is unambiguously female and another referent that is not unambiguously male, a feminine pronoun may legitimately corefer to either referent, as shown in (8). On the other hand, a masculine pronoun in a sentence of this type may not refer to the feminine referent, as (9) demonstrates:

8) The cleaning lady told the accountant that the reporter from the city might introduce her to the French count.

9) The cleaning lady told the accountant that the reporter from the city might introduce him to the French count.

The obtained pattern of priming in these sentences is informative in a number of respects. First, the results for the feminine pronoun sentences showing the neutral referent to be reactivated suggest that unmarked nouns are not automatically
construed as male. Second, the priming pattern in the feminine pronoun cases suggests that pragmatic information does not play a role in restricting the reactivation of referents. For it is surely the case that the more likely antecedent in a sentence such as (8) is the unambiguously female referent. Yet both referents are reactivated. Therefore, the alternative explanation suggested for the results in Experiment 1, that the appearance of multiple reactivation was due to an averaging of priming for referents in the two sentential positions, is not supported. Third, these results indicate that the way in which gender information affects reactivation processes is to restrict activation to referents that do not exhibit incongruence in terms of gender. Thus, unmarked referents such as, "accountant", though often interpreted as male in the absence of context, will not be ruled out as a possible antecedent for a feminine pronoun, but a marked referent such as, "princess" will not be reactivated as a potential antecedent for a masculine pronoun. Therefore, the mechanism that reactivates candidate antecedents focusses on mismatches of the relevant feature.

It was hypothesized in the discussion of results of Experiment 2 that reactivation of the semantics of a referent is preceded by activation of the suffix, and that the absence of a suffix signifies that the referent is singular. Congruence is determined on these grounds, and the referent is accordingly activated or not. The results of the gender experiment do not support this hypothesis. For, if absence of the gender-marking suffix implies that the referent is male, then the unmarked referent in the feminine pronoun cases should not be reactivated. How, then,
are the findings for Experiments 2 and 3 to be reconciled? It appears that feature checking is a necessary component of the reactivation process. The hypothesis that suffixes could be reactivated in isolation provided a solution to the problem of establishing congruence without reactivating the semantic content of the referent. However, this solution is incompatible with the results obtained here. Hence, it must be possible to selectively access those lexical features that are relevant to coreference, whether they are marked by a suffix or are part of the set of semantic features associated with a particular item.

2.5 CONCLUSIONS

The results of these three experiments demonstrate the following: 1) Anaphoric elements trigger immediate reactivation of prior referents. 2) Only those referents for which coreference with an anaphoric element does not violate Binding constraints will be reactivated. 3) Pronominal feature information, such as number and gender, is used to limit reactivation of candidate antecedents. 4) The elimination of a referent as a possible antecedent is a consequence of a mismatch, rather than a match, of the relevant pronominal features. In the case of number, referents are always marked: the absence of a suffix indicates that the referent is singular, and all referents have the potential for mismatch, and hence, the potential to be dismissed prior to reactivation. As for gender, however, the lack of marking does not itself carry a value for this feature, and neutral referents may be reactivated because they fail to mismatch. 5) Establishing congruence may be
accomplished by *selective access* of these features from the complex of semantic properties associated with each referent.
1. The formulation of Binding conditions given here are simplified for clarity of exposition. More precise formulations and details of the theory may be found in Chomsky, 1981.

2. Female referents were nearly always inherently female, such as, "princess" and "niece". Male referents varied: some were inherently male, such as "boy", others were simply more likely to be male, such as "chauffeur", others were (arguably) neutral, such as "doctor".

3. For referent 2, there are only 22 df for the items analysis due to the fact that all the data for one item had to be removed from the analysis: all five subjects in one condition gave erroneous responses to this item.

4. This procedure was not performed in the first experiment, since individual variance was generally within the normal range for this type of experiment. Variance observed in this experiment appeared to be unusually high.

5. Despite the absence of a significant interaction of congruence x target, planned comparisons of means for related vs. unrelated targets were necessary to be able to address the hypotheses that generated this study.

6. It is not clear that male referents may be considered to be "marked" at all, since the masculine counterpart to feminine endings such as "-ess" is "-or" (as in "waitress"/"waitor"), which is homophonous with the gender-neutral agitative suffix, "-er" (as in "swimmer", "painter", etc...).
<table>
<thead>
<tr>
<th></th>
<th>Pronoun</th>
<th>Reflexive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
</tr>
<tr>
<td>Referent 1</td>
<td>709</td>
<td>752</td>
</tr>
<tr>
<td></td>
<td>43 *</td>
<td></td>
</tr>
<tr>
<td>Referent 2</td>
<td>654</td>
<td>712</td>
</tr>
<tr>
<td></td>
<td>58 *</td>
<td></td>
</tr>
<tr>
<td>Referent 3</td>
<td>711</td>
<td>690</td>
</tr>
<tr>
<td></td>
<td>-21</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Mean response latencies (in msec) to targets in different treatment conditions, Experiment 1. Values for referents that may refer to the anaphoric element are presented in italics.

* p < .05 (for both subjects analysis and items analysis)
<table>
<thead>
<tr>
<th>Type of Pronoun</th>
<th>Singular Pronoun</th>
<th>Plural Pronoun</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related Target</td>
<td>Unrelated Target</td>
</tr>
<tr>
<td>Congruent Referent</td>
<td>657</td>
<td>690</td>
</tr>
<tr>
<td>Incongruent Referent</td>
<td>695</td>
<td>682</td>
</tr>
</tbody>
</table>

Table 2. Mean response latencies (in msec) to targets in different treatment conditions, Experiment 2. Values for referents that may refer to the pronoun (the "congruent" condition) are presented in italics.

+ p < .05 (for subjects analysis)
### TYPE OF PRONOUN

<table>
<thead>
<tr>
<th>Masculine Pronoun</th>
<th>Feminine Pronoun</th>
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</thead>
<tbody>
<tr>
<td>Related Target</td>
<td>683</td>
</tr>
<tr>
<td>Unrelated Target</td>
<td>727</td>
</tr>
<tr>
<td>Priming</td>
<td>44 *</td>
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<tr>
<td>Congruent Referent</td>
<td></td>
</tr>
<tr>
<td>Incongruent Referent</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>674</td>
</tr>
</tbody>
</table>

Table 3. Mean response latencies (in msec) to targets in different treatment conditions, Experiment 3. Values for referents that may refer to the pronoun (the "congruent" condition) are presented in italics.

* p < .05 (for subjects and items analysis)
+ p < .05 (for subjects analysis)
CHAPTER 3: COREFERENCE PROCESSING DURING SENTENCE COMPREHENSION:

A REVIEW OF ON-LINE RESEARCH
3.1 INTRODUCTION.

The research examined here focusses on a core feature of human sentence processing: how the correct coreferential relations are established among elements within a sentence. The specific focus is on the processing of those noun phrases (or "NP's") which bear little semantic content, and which normally refer back to a previously-mentioned NP, or antecedent. Such "referentially-dependent" NPs include pronouns (e.g. "she" or "her"), anaphors (such as "himself"), and empty NP's, such as implicit subjects and objects.

A number of recent studies (Corbett & Chang, 1983, MacDonald, 1988, Bever and McElree, 1988, Tanenhaus, Carlson, and Seidenberg 1985) have demonstrated that during sentence processing, such referentially-dependent elements trigger a "reactivation" of the noun phrase to which they refer. For example, Bever & McElree (1988) have shown, using a sentence-final word recognition probe, that if a referentially-dependent element intervenes between the antecedent and the end of the sentence, reaction times to the probe will be speeded, as compared to the same probe following control sentences containing no coreferring elements. For instance, immediately following a sentence such as "The astute lawyer, who faced the female judge, hoped he would speak during the trial." (presented visually, clause by clause), subjects were faster to indicate that the word "astute" had appeared in the sentence, than when presented with a sentence such as, "The astute lawyer, who faced the female judge, hated the long speech during the trial.". Notice that the probe was not the
noun, "lawyer", but rather, its modifier, indicating that the entire noun phrase is reactivated, not just the head.

These findings are compatible with three quite different accounts of the reactivation process. These may be characterized as follows: 1) A referentially-dependent NP may cause reactivation of all previously-mentioned NP's. These activated NP's would then be considered for their suitability as antecedent. 2) A referentially-dependent NP may give rise to reactivation of all and only those NP's that bear the appropriate structural relation to the dependent item. A variant of this hypothesis, involving the notion of interpretative strategies or heuristics, might suggest that where two or more referents are structurally permissible as antecedents, there will be reactivation of only one; the one that is nearest to the referentially-dependent element (see, for example, Frazier, Clifton, and Randall, 1983), or the one that carries a parallel grammatical function (Grober, Beardsley, and Caramazza, 1978). 3) A dependent NP causes only the most appropriate preceding NP to be reactivated.

These accounts differ primarily in their characterization of the time course of information availability. At some point during coreference processing, information about sentence structure, on one hand, and semantics, pragmatics, discourse context, on the other, will all come into play. These three alternatives make different predictions about when and how these types of information have their effect: to eliminate inappropriate NP's from a candidate set of activated NP's, or to restrict the candidate set by constraining which prior NP's are reactivated.
There is some evidence that pragmatic information does not constrain initial reactivation of a candidate set of antecedents. Corbett & Chang (1983) presented subjects with two-clause sentences containing two potential antecedents in the first clause, and a subject pronoun in the second. The correct antecedent for the pronoun was either the first or second mentioned name in the first clause; which of the two was most appropriate depended entirely on pragmatic factors. For example, in the sentence, "Ellen aimed a pistol at Harriet, but she did not pull the trigger.", "she" most likely refers to "Ellen"; clearly, what guides this judgment about antecedence is our knowledge about the world (e.g. that pistols have triggers and that one must be holding the pistol to pull the trigger, etc...) An end-of-sentence name-verification task indicated that reaction times were facilitated to both potential antecedents of a pronoun, not just to the appropriate one. This finding, clearly incompatible with the third account described above, supports either of the first two: all previously mentioned NP's are reactivated; all and only those NP's that are in an appropriate structural position to act as antecedent are activated.

The analysis of experimental evidence presented below speaks to the question of whether or not syntactic constraints on coreference may act to restrict the reactivation of prior NP's. The evidence provides strong support for the notion that reactivation is restricted by grammatical constraints: the initial set of candidate antecedents contains all and only those referents that bear the appropriate syntactic relation to the referentially-dependent NP.
Before examining relevant experimental findings, we will outline the syntactic principles that constrain coreference relations. These provide the framework against which the more general cognitive constraints on processing may be evaluated.

3.2 Binding and Control.

The following discussion of constraints on coreference assumes the approximate framework of Government and Binding ("GB") Theory. While this theory differs in some important respects from other contemporary syntactic theories (such as GPSG, see, for example, Gazdar, 1982) and LFG (see Bresnan, 1982), the facts described below are captured in roughly similar ways, and the differences among these theories do not compromise the interpretation of the experimental findings to be reviewed.

Overt NPs.

 GB divides phonologically overt NPs into three types: anaphors, pronominals, and R(eferential)-expressions. Anaphors (such as "herself"), and pronominals (such as "her") are closed class items, and all remaining overt NPs constitute R-expressions, including names ("John") and structurally complex NPs ("the tall boy from Chicago"). These are illustrated in (1a-c).

1) a. Bill saw himself.
    b. Bill saw him.
    c. Bill saw John.

The Binding Theory is a system of three principles, or conditions, each governing the coreference possibilities of the different types of NPs. A simplified version of these conditions is
given in (2) (for a more precise formulation, see Chomsky, 1981.).
(The term "bound", below, may be interpreted as, "identified with an antecedent").

2) a. Condition A: An anaphor must be bound "locally".
   b. Condition B: A pronoun must be free (i.e. not bound) "locally".
   c. Condition C: An R-expression must be free.

Consider the following sentences (coreference is shown by indices):

3) a. Mary said that Susan₁ cut herself₁.
   b. Mary(₁) said that Susan cut her(₁).

Condition A states, roughly, that an anaphor such as "herself" must have its antecedent within its clause. In (3a), "Susan" is the only referent appearing within the same clause as "herself"; "herself" is bound by "Susan". A pronoun, on the other hand, cannot be bound by a referent within its clause; hence, in (3b), "her" cannot refer to Susan. Note that, while "Mary" is the most appropriate antecedent for "her" in this sentence, Condition B does not force a particular referential expression to bind the pronoun "her". Condition B asserts only that "her" must not be bound by "Susan".

As the examples above illustrate, an anaphor must be bound by a referent that is within its clause. However, there may be more than one referent within the same clause as the anaphor, as in (4).

4) A friend₁ of Susan's cut herself₁.

In (4), "herself" is bound by "a friend", not by "Susan". Note that these referents bear different structural relations to the anaphor. In particular, "a friend", but not "Susan", "c-commands" the
anaphor. A constituent is said to c-command another if "the first branching node dominating one also dominates the other". Hence, "a friend" c-commands "herself", but "Susan", contained within a prepositional phrase, does not. Hence, Condition A is more appropriately formulated as:

5) Condition A: An anaphor must be bound locally by a c-commanding NP.¹

This notion is also relevant in characterizing which referents may not bind a pronoun. In sentence (6) below, the pronoun, "her" may refer to either "Susan", or "Mary", but not "a friend".

6) Mary(i) said that a friend of Susan's(i) cut her(i).

Thus, Condition B may be reformulated as follows:

Condition B: A pronoun must not be bound by a local c-commanding NP.

Empty NPs.

Binding theory extends also to empty NPs. Within GB theory, there are three phonologically empty NPs: NP-trace, wh-trace, and PRO. The first two are derived by movement. In this theory, there are two distinct levels of syntactic representation. The level of D-Structure is defined as a structural representation of predicate/argument structure. Roughly, the D-Structure of a sentence represents the phrasal projections of lexical items (NP, VP, etc...); in D-Structure, every argument of a verb is in a local structural relation to it. So, for example, in English, the object of a verb is in a position immediately to the right of the verb; at this level, the direct object of a verb must appear in that particular position. Various movement processes may move a phrase or word to a position
different from its interpreted semantic position; the result of applying such movement processes to a D-Structure yields the corresponding S-Structure. S-Structure serves as the input to the phonological component of the grammar; in this sense S-Structure is the pronounced representation, and is the syntactic structure most immediately available to the parser. When a NP moves, it leaves a trace (a phonologically non-overt NP), which is coindexed with it. Consider the following ("t" indicates a trace).

7) The actress₁ was persuaded \( t₁ \) by the dentist to go out.
8) That's the actress₁ whom₁ the dentist persuaded \( t₁ \) to go out.

The passive construction, as in (7), involves movement of the D-Structure object ("the actress") to the empty subject position of the sentence. Occupying the object position of the verb is a trace which is coindexed with the moved NP, "the actress". In relative clauses, such as (8), it is not "the actress" that moves, but rather the relative pronoun, "whom". ("Whom" is in turn linked to "the actress", though coreference in this instance is not guided by binding principles, and is established at a level of representation that invokes semantics, the level of "logical form".) There is an important difference between (7) and (8). Though they both involve movement of an NP, and hence, contain a trace in object position, the traces are different in kind, and obey different binding conditions. Notice that the trace in (7)--a NP-trace--is bound by a nearby antecedent. Thus, like overt anaphors, NP-traces are subject to Condition A. By contrast, the trace in (8)--a wh-trace (or trace of a moved wh-phrase)--cannot be locally bound; the wh-trace cannot refer to the subject of its clause (in this case, "the dentist"). In a variety of instances, wh-trace behaves much like an R-expression.
with respect to binding, hence, \textit{wh}-trace is subject to Condition C. Yet sentences such as (8) indicate that there is a unique antecedent for the \textit{wh}-trace, so there must be other constraints which limit the coreference possibilities for this type of trace.

\textit{Theta Role Assignment and Argument Position.}

The relative pronoun in (8) appears in a structural position that prevents it from receiving a "thematic" (or "theta") role from the verb. A "theta" role is a grammatical or functional role (such as "agent") played by each argument in a sentence. The "theta criterion" states that each NP must receive one and only one theta role. Further, an NP must appear in an "argument position" to be assigned a theta role directly by the verb. The relative pronoun in (8) occupies a "non-argument" position, yet its trace, which appears immediately following the verb, occupies an "argument" position. The trace receives a theta role directly from the verb; the relative pronoun "inherits" this theta role. The fact that there is a unique antecedent for \textit{wh}-trace in sentences such as (8) is thus explained by the appearance of the antecedent in a nonargument position and the trace in an argument position, and the restriction that a NP may receive only one theta role. As for passive sentences such as (7), this restriction also applies: verbs in the passive voice do not assign a theta role to the subject position; therefore, like the displaced relative pronoun in (8), the moved NP must inherit its theta role from the trace.

\textit{Control Theory.}
There is another type of phonologically empty NP, and that is the empty subject, or PRO. PRO behaves both like an anaphor and like a pronoun, in that in some instances it has a local antecedent, and in other instances, it does not. Since it would be meaningless to claim that an element is sometimes locally bound and sometimes locally free, constraints on coreference of PRO fall outside the domain of Binding theory. Further, since PRO is "base-generated" (i.e. it is represented at D-Structure), it is not the result of movement, hence its antecedent cannot be determined by an examination of argument vs. non-argument positions. In fact, the antecedent of PRO cannot reliably be determined by structural positions at all.

Control Theory attempts to characterize the structural relation that holds between PRO and its antecedent. For the most part, PRO is coindexed with the nearest c-commanding NP, as in (9) and (10):

9) Sue convinced Anne$_1$ PRO$_i$ to entertain the children.
10) Anne$_i$ tried PRO$_j$ to entertain the children.

It is commonly held that information about the controller of PRO is encoded in the lexical entry for each verb. Thus, when a verb subcategorizes for an infinitival complement, the antecedent of PRO will be specified as being either the subject or object of the matrix verb. While it is usually the case that the object of a verb will control PRO, some verbs have exceptional control properties, such as the verb, "promise". In these cases, the subject of the verb controls PRO, even if the subject is not the nearest c-commanding NP:

11) Sue$_i$ promised Anne PRO$_i$ to make dinner.

In addition to exceptional cases like "promise", the subject of the matrix clause will always be the antecedent of PRO--no matter
what the matrix verb—when the embedded clause is a *rationale clause*, as in (12):

12) Sue₁ hired Anne PR0₁ to placate the children.

The rationale clause in (11) expresses the reason that Sue hired Anne: Sue hired Anne *in order* to placate the children. The verb "hire" cannot be specially marked as a "subject control verb" (as is "promise"), since the subject of the verb does *not* control PRO in sentences in which the embedded clause is a *purpose clause*, such as in (13).

13) Sue hired Anne₁ PR0₁ to placate the children.

In this case, the embedded clause describes the purpose for which Anne was hired: to placate the children. Examples such as (12) and (13) indicate that the embedded clause must be fully processed and the intended meaning discerned before the antecedent for PRO may be determined. The mere existence of rationale clauses and purpose clauses makes control theory necessarily a semantic theory rather than a syntactic one. If establishing the antecedent for PRO involves processing the semantics of the embedded clause and determining the relation of this clause to the matrix clause in instances such as (12) and (13) above, then even in sentences for which it is *unnecessary* to perform elaborate semantic processing (such as (9) and (10), above), the entire sentence must be processed deeply enough to be able to determine that the semantics of the embedded clause do not play a role.

*Summary of NP types and syntactic constraints on coreference.*

In brief, for the NP types discussed above, the coreference constraints are:
1. *Overt anaphors* and *NP-trace* must be bound by a c-commanding NP in a local domain (Condition A).

2. *Pronouns* must be free in a local domain (Condition B).

3. *R-expressions* and *wh-trace* must be free (Condition C). *Wh-trace* is coindexed with a NP in a non-argument position.

4. *PRO* may be bound by some c-commanding NP, (often depending upon the control characteristics of the preceding verb).

3.3 **EMPIRICAL EVIDENCE FOR SYNTACTIC CONSTRAINTS ON REACTIVATION.**

The research reviewed here examines reactivation patterns associated with the NP types described above. I have restricted this review to studies which use on-line techniques to measure reactivation. Compared to end-of-sentence probes, on-line measures tend to be less prone to conscious reflection on the part of the subjects, since the subjects are engaged in listening to the sentence while they respond to the task. Further, while the post-sentence probe-recognition task may reflect either reactivation that has occurred automatically in response to the presence of a referentially-dependent NP, or reactivation brought about by the probe recognition task itself (which promotes a memory search), on-line tasks such as lexical decision are more likely to tap automatic, unconscious processes.

Let us first review the reactivation findings for *wh-traces*, *NP-traces*, and *overt anaphors*. These are the cases for which the syntax points to a unique antecedent. Then we will examine the reactivation patterns in sentences in which there are several potential antecedents: sentences containing *pronouns*, and *PRO*. 
Wh-trace.

A number of studies have examined the reactivation of an antecedent in sentences containing wh-trace.

Using a cross-modal paradigm, Swinney, Ford, Frauenfelder, and Bresnan (cited in Swinney, Ford, and Bresnan, 1988) examined reactivation patterns in response to wh-traces contained in relative clause constructions. Sentences were presented auditorily, and subjects were asked to make a lexical decision to visually presented word/nonword targets. The appearance of the targets on a CRT screen coincided with the portion of the sentence in which the trace would be represented, as shown in the following sentence ("t indicates "trace", and "#" indicates the the probe point; subscripts indicate coreference).

14) The policeman saw the boy that accused of the crime.

In the critical cases, a target was either an associate of one of the previously mentioned NP's, or a control word matched in length and frequency to the associate. Whether or not there is priming is generally determined by a comparison of average reaction time to make a lexical decision on the associate and average reaction time to the control word. A significant difference between them suggests priming, and, in this context, indicates activation of a prior referent. Note that although the antecedent of the trace in this instance is the relative pronoun, "that", rather than the head of the relative, "boy", it is reasonable to assume that, since they corefer, the semantics of the head are inherited by the relative
pronoun. Therefore, probing with an associate of "boy" ought to provide a measure of priming for the antecedent.

To ensure that any finding of activation actually signifies re-activation of a referent, there were two additional probe locations: just prior to the verb, "accuse", and 300 msec. following the initial probe point. The three probe positions are shown below:

15) The policeman saw the boy that the crowd at the party # accused t1 # of the # crime.

The following patterns of priming were obtained. Figures indicate magnitude of priming (i.e. the difference between the mean response time for an unrelated matched control target and the mean reaction time for related targets). Significant priming is shown by the asterisk.

<table>
<thead>
<tr>
<th>Probe Point</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boy</td>
<td>12</td>
<td>27*</td>
<td>27*</td>
</tr>
<tr>
<td>Crowd</td>
<td>44*</td>
<td>19</td>
<td>.8</td>
</tr>
</tbody>
</table>

Priming for "boy" becomes significant only after the embedded verb, where the representation contains a trace. There is significant activation of "crowd" only at a point several hundred msec. after the actual occurrence of "crowd" in the sentence; after this point, it diminishes. This suggests that the significant priming of "crowd" at the first probe point was simply due to residual activation. A comparison of the patterns of priming for the two referents indicates that a trace does give rise to a reactivation of its antecedent, and only its antecedent, in this case, "boy". Note that since there was no probe for the activation of "policeman"
in this experiment, one cannot conclude that a trace reactivates just its antecedent. However, a follow-up study did demonstrate reactivation of only the appropriate antecedent for trace. Swinney et al. (1988) used a naming paradigm to determine priming of the three referents in these sentences. Here, again, priming for "crowd" was nonsignificant, as was priming for "policeman"; only "boy" was significantly activated.

This result, that a wh-trace triggers reactivation of its antecedent, has been replicated by a number of investigators. Tanenhaus, Carlson, and Seidenberg (1985), report a study which used a cross-modal "rhyme priming" methodology. This study looked at reactivation of the antecedent of wh-trace, again in relative clauses. Two versions of each experimental sentence were created, such as, "The man was surprised at which beer/wine the judges awarded the first prize to t". Each version was followed by a target which rhymed with one of the antecedents of trace; in this case, for example, the word "fear" was displayed. Response latencies to a lexical decision on "fear" was compared for the two sentence versions to obtain a measure of priming. Their hypothesis is this: if the end-of-sentence trace causes the antecedent to be reactivated--specifically, if the trace causes the phonological properties of the antecedent to be reactivated--then reaction times ought to be facilitated when the target rhymes with the antecedent, as compared to instances in which the target does not rhyme with the antecedent. Thus, responses to "fear" were expected to be faster when the antecedent is "beer" than when the antecedent is "wine". Their results support their hypothesis: responses to rhymes are faster
than responses to non-rhymes, suggesting that the trace triggered reactivation of its antecedent.

This finding obtains even when the antecedent is semantically inappropriate as the antecedent of a wh-trace. Using the cross-modal priming paradigm, Nicol and Osterhout (1988) examined reactivation patterns in sentences such as, "That's the actress that the dentist from the new medical center in town had planned/invited to go to the party." In both types of sentences, there was priming for "actress" immediately following the embedded verb, suggesting that a wh-trace is postulated following verbs such as "invite" (after which a trace must be represented, since this verb is transitive), as well as after verbs such "plan" (which optionally take a NP complement). Hence, despite the fact that one cannot "plan the actress", this referent is reactivated. These results are presented in greater detail below in the discussion of PRO.

Further support for this finding comes from a study by Garnsey, Tanenhaus, and Chapman (1988), who measured evoked brain potentials of their subjects during the controlled serial visual presentation of sentences containing relative clauses. They exploited the fact that the implausibility of a word in context results in a particular EEG pattern (referred to as "N400"); by constructing sentence pairs that contained as the antecedent of the wh-trace an item that was either contextually plausible or implausible, such as in (16):
16)  a. The mother found out which book the child read \( \ell_t \) in school.
 b. The mother found out which food the child read \( \ell_t \) in school.

They created, in addition, a pair of control sentences that did not contain a trace:

17)  a. The mother found out whether the child read the book in school.
 b. The mother found out whether the child read the food in school.

They predict that the appearance of the contextually implausible object, "food", in (17b) should produce N400, whereas the plausible object, "book" should not. As for the relative clause sentences (16a) and (16b), they expect that if the antecedent of the wh-trace is reactivated immediately, then N400 ought to occur after the verb "read" in (15b) only. Their EEG data show the N400 as predicted: N400 occurs immediately following the verb, "read" in (16b) and (17b), but not in the plausible sentences, (16a) and (17a). Thus, this study provides additional evidence that wh-traces reactivate their antecedents. It also has interesting implications for the time-course of information use within the processing system. Given the above finding by Nicol and Osterhout, it would be expected that the implausibility of the antecedent would not prevent it from being reactivated. If it had, there would be no N400 effect in (16b). Yet the presence of N400 at this point indicates that once reactivated, the anomaly is registered, and further, that it is registered relatively quickly.

In sum, these studies indicate that a wh-trace triggers 1) immediate reactivation of its antecedent, and 2) reactivation of only the correct antecedent (in terms of structural constraints); and 3) reactivation of the antecedent occurs independently of plausibility.
considerations. This suggests that information concerning argument position and the requirement that NPs receive theta roles is used to restrict reactivation of potential antecedents.

NP-trace.

Is there evidence that NP-traces exhibit similar patterns of reactivation? Studies which examine the reactivation of an antecedent in sentences containing NP-trace are surprisingly few. Bever and McElree (1988) have shown that passive sentences yield results that are similar to results obtained for sentences containing other types of referentially-dependent NP's: their end-of-sentence word recognition probe showed facilitation for the word "astute" following a sentence such as, "The astute lawyer who faced the female judge was suspected t constantly" (vs. the control sentence containing the adjective, "suspicious" instead of "suspected"). This suggests that NP-traces do cause their antecedents to be re-accessed. However, there is evidence that the pattern of reactivation is unlike that found for wh-traces. In an on-line study, Osterhout (personal communication) probed for the activation of "the dentist" in sentences pairs such as the following: "The dentist from the new medical center in town invited the actress to go to the party."/"The dentist_t from the new medical center in town was invited t by the actress to go to the party." Using the cross-modal task, Osterhout probed just after the verb, "invite", and at points 500 msec. and 1000 msec. downstream from this point. Although the priming found for "dentist" did not reach significance, it is worth noting that there was priming for "dentist" only in the passive sentence, and further, only at the second two probe points.
If we make the provisional assumption that NP-traces do reactivate their antecedents, how can we account for the difference in time course of reactivation for NP-traces compared with wh-traces? In both cases, there is a unique antecedent that is identifiable by its structural position. The lag in priming following the NP-trace makes more sense if we take a closer look at the differences in the syntax of the two types of sentences in which these traces appear. The structure of wh-questions and relative clauses is such that the parser may expect an upcoming trace following the embedded verb. Recall that the relative pronoun, "who" is in a non-argument position and must be coindexed with a trace downstream to receive a theta role. If information relevant to argument positions is available to the parser, it is likely that a trace may be posited at the first point where trace in such constructions is most likely to occur: after the verb. There is empirical support for this claim. Studies by Crain and Fodor (1985) and Stowe (1986) examined the processing of wh-questions and relative clauses using a self-paced reading task. Their experiments show that reading times increase at the object position in a wh-clause where there is an overt NP in that position rather than a trace. So, for example, in Stowe's study, reading times were elevated (compared to reading latencies for the same item in a non-wh-sentences) at the word "us" in the following: "My brother wanted to know who Ruth will bring us home to t at Christmas." This finding suggests an expectation to posit a trace after the embedded verb. Thus, the structure of relative clauses and wh-questions provides an unambiguous cue that there is trace downstream in the sentence. Passive constructions, on the other hand, do not provide such a cue. In fact, it may be difficult for
the parser to determine that there even *ought* to be a trace following the verb. An important fact about the passive construction is that it coincides in structure with active sentences containing a temporal or locative prepositional phrase. Notice, for instance, that the structure of the sentence, "The runner was worn out by the time the race was over." resembles the structure of the passive sentence, "The runner was worn out by the strenuous training.". Neither the configuration of these sentences, nor information about argument positions will indicate unambiguously that a trace should be postulated following the verb in the passive sentence. In addition to having access to this information, the parser would need to be able to determine the following. 1) That a term such as "worn out" is actually a verb rather than a deverbal adjective (information that we assume to be immediately available to the parser, since access to grammatical category is necessary for the construction of a parse tree). 2) That the preposition, "by" has the agentive reading. This can only be conclusively determined once the semantics of the object of "by" have been processed (e.g. "strenuous training" can wear someone out, but "the time the race was over" cannot); since this disambiguating information about the interpretation of "by" appears relatively late in the sentence, one would expect a delay in the postulation of the trace.² The double ambiguity of the verbal element (verb vs. deverbal adjective) and the preposition (agentive "by" vs. temporal/locative "by") make it unclear that a sentence is actually passive, and that a trace should be represented after the verb. In those instances where the verbal element is unambiguously a verb (e.g. "hit"), the meaning of the preposition, "by" is irrelevant, since the tense of the verb would be enough to establish
that the sentence is passive. We suspect, however, that truly unambiguous verbs are relatively uncommon. Given the ambiguity of the passive construction, it is not surprising that the reactivation of the antecedent of NP-trace follows a time course different from that found for wh-traces.³

*Overt Anaphors vs. Pronouns.*

Let us now turn to reactivation patterns that obtain following the overt counterpart to the NP-trace. Recall that Condition A of the Binding theory states that an anaphor must be bound by a local binder, normally the subject of the clause in which the anaphor appears. There is evidence that an overt anaphor also triggers reactivation of its antecedent. Nicol (1988a) examines the reactivation patterns of referents in sentences such as the following:

18) The boxer told the skier that the doctor₁ for the team would blame himself₁ # for the recent injury

A cross-modal task revealed that immediately after the anaphor, there was significant priming of the antecedent, "the doctor", but nonsignificant priming of "the boxer", and "the skier". This finding is compatible with two explanations: 1) The reactivation of prior referents in response to the anaphor is restricted to only the binder of the anaphor; 2) The priming effect found here could simply reflect the residual activation of "the doctor". This second possibility is discounted by the following. Sentence (18) above was contrasted with (19), in which the embedded clause contains a pronoun:

- 109 -
19) The boxer$_i$ told the skier$_i$ that the doctor for the team would blame him$_i$ # for the recent injury

Again, all three referents were tested. Magnitude of priming for each referent within both the pronoun sentences and anaphor sentences is given below.

<table>
<thead>
<tr>
<th>Referent</th>
<th>Anaphor</th>
<th>Pronoun</th>
</tr>
</thead>
<tbody>
<tr>
<td>boxer</td>
<td>-1</td>
<td>43*</td>
</tr>
<tr>
<td>skier</td>
<td>11</td>
<td>58*</td>
</tr>
<tr>
<td>doctor</td>
<td>104*</td>
<td>-21</td>
</tr>
</tbody>
</table>

Results for the pronoun sentences indicate no priming for "doctor", but significant priming for both "boxer", and "skier". The pattern obtained for both sentence types suggests that the activation of a candidate set of antecedents occurs in compliance with syntactic constraints (Binding conditions A and B, in this case). It is important to note in this instance that Binding theory does not dictate the precise pattern of reactivation in this experiment. Recall that Condition B states only that the pronoun must be free in a local domain; hence, a finding of no reactivation of a prior referent would also be compatible with this constraint.

This finding that the reactivation of referents in response to a pronoun respects Condition B of the Binding theory was replicated by Swinney, Ford, Bresnan, and Nicol (cited in Swinney, Ford, and Bresnan, 1988), who examined reactivation patterns in sentences such as (20).

20) The boxer$_i$ visited the doctor$_j$ that$_j$ the swimmer at the competition had advised him$_i$ to see $t_j$ about the injury.

In this sentence, "boxer" is the only structurally appropriate antecedent of the pronoun "him". The second NP, "the
doctor", is coindexed with the relative pronoun, which must bind a trace rather than an overt element. Finally, the third NP, "the swimmer", cannot corefer to the pronoun since it is the subject of the clause in which the pronoun appears; coindexing these two NPs would violate condition B of the Binding theory.

Patterns of priming for each potential antecedent varied according to the point in the sentence that correlated with the lexical decision, as shown below:

The boxer visited the doctor that the swimmer at the competition had # advised # him # to see about the injury.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boxer</td>
<td>23</td>
<td>20</td>
<td>51*</td>
</tr>
<tr>
<td>doctor</td>
<td>32</td>
<td>56*</td>
<td>42*</td>
</tr>
<tr>
<td>swimmer</td>
<td>9</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

Activation levels for the appropriate antecedent, "boxer", only reached significance at the third probe point, i.e. just after the pronoun to which it refers. There is significant priming for "doctor" just after the embedded verb, with continued priming after the pronoun. There is no significant priming for "swimmer" at any point. For the referents, "boxer", and "swimmer", this pattern of priming conforms to hypothesis that syntactic constraints restrict which referents are reactivated. However, the priming found for "doctor" at probe points 2 and 3 require an explanation. Given the results of studies which examined reactivation of referents at the point of a wh-trace, and the fact that there is priming for "doctor" prior to the occurrence of the pronoun, it seems reasonable to assume
that a trace has been erroneously postulated following the embedded verb, and that the only appropriate antecedent for this trace is consequently reactivated. Suppose that the experimental sentences had been constructed as follows: "The boxer visited the doctor that the swimmer at the competition had advised about his backstroke". In such cases, there would be a trace following the verb, and the trace would be linked to "doctor". If traces are postulated immediately upon processing the embedded verb, no matter what follows, then in sentences such as (20) one would expect a trace to be represented after the verb, "advise", and thus, expect the antecedent of the trace to be reactivated. The overall pattern of priming for these referents raises an interesting question. While the account presented here concerning the activation of "doctor" at points 2 and 3 provides a sufficient explanation for the data, it implicitly assumes that different syntactic constraints are simultaneously taken into account. Consider the following. Suppose that a pronoun triggers reactivation of all prior NP’s except the local c-commanding NP. In the sentence above, both "boxer", and "doctor" would be reactivated at point 3. Suppose also that a trace is erroneously postulated following the verb: "doctor" would be reactivated in response to the postulation of the wh-trace. The overall pattern of priming would look exactly like what was obtained. Hence, it is unclear, at this point, whether a pronoun gives rise to the reactivation of all prior NP’s except the local c-commanding NP, or to the reactivation of only those NP’s that are not coindexed to some other referentially-dependent element. In other words, this result leaves open the question whether different types of constraints are consolidated prior to reactivating referents.
The results for the pronoun cases suggest that there is multiple activation of referents in sentences in which there is more than one referent that may be coindexed with the pronoun. In other words, where semantic or pragmatic information is necessary to determine which of two or more referents is the actual antecedent of the pronoun, all candidates are reactivated for consideration. Recall that in the discussion of PRO, above, the claim was put forth that coreference of PRO with an antecedent is often dependent on semantics. Hence, one would expect activation of multiple referents in response to PRO. The following studies address this question.

Using the cross-modal technique, Nicol (see Chapter 1) examined priming of both previously-mentioned referents in sentences such as (21).

21) a. There is the actress₁ that₁ the dentist from the new medical center in town # had invited PRO₁ to # go to # the party.  
   1  2  3

   b. There is the actress₁ that₁ the dentist₁ from the new medical center in town # had planned PRO₁ to # go to # the party with t₁.  
   1  2"  3

In (21a), there is a transitive verb in the embedded clause for which the direct object is a trace of the relative pronoun. PRO in this sentence is coindexed with the nearest NP, the trace. Thus, PRO is identified with "the actress". In (21b), however, the embedded clause contains an intransitive verb, and PRO is therefore identified with the preceding subject, "the dentist". These sentences were designed to test the on-line application of processing strategies in determining the antecedent of PRO, in response to
Frazier, Clifton, and Randall (1983). They hypothesized that control information would be unavailable to the parser during the initial analysis of such sentences. Hence a strategy, which they call the
Most Recent Filler Strategy, is invoked to assign PRO an antecedent: PRO is linked to the most recent potential antecedent. They would expect the results of this experiment to show priming of "dentist", and only "dentist", in both sentence types at the appropriate point in the sentence (i.e. probe point 2). The following patterns of priming were obtained:

<table>
<thead>
<tr>
<th>Transitive Verbs</th>
<th>Intransitive Verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e.g. &quot;invite&quot;)</td>
<td>(e.g. &quot;plan&quot;)</td>
</tr>
<tr>
<td><strong>Referent</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Probe Point</strong></td>
<td><strong>Probe Point</strong></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>actress</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>75*</td>
</tr>
<tr>
<td></td>
<td>57*</td>
</tr>
<tr>
<td>dentist</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
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<tr>
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<td>36</td>
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<tr>
<td></td>
<td>71*</td>
</tr>
<tr>
<td></td>
<td>48*</td>
</tr>
</tbody>
</table>

Considering, first, sentences containing transitive verbs in the embedded clause, only "actress" becomes reactivated after the embedded verb. There is no significant priming for "dentist" at any of the probe points, indicating that there is no evidence that the Most Recent Filler Strategy is applied on-line. The result for transitive verb sentences, taken in isolation, suggests that only the correct antecedent for PRO is reactivated. However, this conclusion is not supported by the data for sentences containing intransitive verbs. In the intransitive verb sentences, only "dentist" should be activated, since "dentist" is the antecedent of PRO. Instead, exactly the same pattern of priming was obtained for the intransitive verb sentences as for the transitive verb sentences. The activation
of "actress" following the transitive verb is understandable if the
effect is interpreted as a response to the wh-trace that is
represented after this verb. As shown above, wh-traces do give rise
to reactivation of the head of the relative clause, in this case,"actress". However, there is no trace following the intransitive
verb, so "actress" should not be reactivated in such sentences.
Considering only probe points 2 and 3, a possible explanation is that
"actress" is in a salient position within the sentence, hence, the
activation of "actress" is maintained throughout. However, the lack
of significant priming for "actress" at the first probe point does
not support this hypothesis. I would like to argue, instead, that a
trace is postulated following intransitive verbs as well as
transitive verbs. Notice that verbs such as "plan" do take an NP
complement, but they normally take inanimate NPs, not animate ones
(as in "plan the trip"), so that in sentence constructions such as
those used in this experiment, these verbs appear to be intransitive.
The set of intransitive verbs that appear in the experimental
sentences actually consist of equal numbers of quasi-intransitive
verbs like "plan", and true intransitive verbs such as "hesitate",
which do not take NP complements of any kind. A follow-up study
(Nicol and Osterhout, 1988) which contrasted these two types of
intransitive verbs indicates that it is only after the quasi-
intransitives that there is significant priming of the head of the
relative (e.g. "actress). Thus, it appears, then, that the
activation of "actress" following intransitive verbs in this study is
actually due to postulation of a trace in a subset of these verbs.
Since PRO is always linked to the wh-trace in such constructions, it
is unclear whether or not the activation of "actress" also
corresponds to the presence of PRO. It is necessary to look at sentences in which PRO and trace are not contiguous in order to examine reactivation in response to PRO. The next study addresses this issue.

Again using the cross-modal technique, Nicol (see Chapter 1) presented sentences that were comprised of a matrix clause containing two potential antecedents and an infinitival clause. The matrix clause was either in the active voice or passive voice, hence the linear position of the correct antecedent varied. Within each sentence, referents were probed at five points, as shown in (22). The first point was just after the "to" in the infinitive; with respect to this point, the next four probes occurred 500 msec., 1000 msec., 1200 msec., and 1500 msec. downstream.

22) a. The actress invited the dentist from the new medical center PRO to # go to the party at the mayor's # house #.

b. The actress was invited by the dentist from the new medical center PRO to # go to the party at the mayor's # house #.

In (22a), the antecedent of PRO is "dentist"; in (22b), it is "actress". The activation patterns for these two referents within each sentence type is as follows:

The actress invited the dentist...

PRO to # go to the party at the mayor's # house #.

<table>
<thead>
<tr>
<th></th>
<th>actress</th>
<th>dentist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>37*</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>77*</td>
</tr>
<tr>
<td></td>
<td>31*</td>
<td>6</td>
</tr>
</tbody>
</table>
The actress was invited by the dentist... PRO to # go to the party at the mayor's house.

<table>
<thead>
<tr>
<th>actress</th>
<th>19</th>
<th>-8</th>
<th>29</th>
<th>32*</th>
<th>40*</th>
</tr>
</thead>
<tbody>
<tr>
<td>dentist</td>
<td>19</td>
<td>31</td>
<td>48*</td>
<td>2</td>
<td>-3</td>
</tr>
</tbody>
</table>

At the first two probe points, there is no significant priming for either antecedent. At the third point, only the "recent filler" ("dentist") is significantly primed in either sentence type. At the fourth position, only the actual antecedents are significantly activated: "dentist" in the active sentence, and "actress" in the passive sentence. At the final probe point, only the "distant filler" is primed in either type of sentence. First, these results confirm the above finding that the Most Recent Filler Strategy does not appear to be invoked during the processing of sentences containing empty subjects. In addition, these results support the hypothesis that all structurally appropriate referents are reactivated. With respect to activation of multiple referents, PRO is similar to pronouns, and this is exactly what was predicted. Yet reactivation patterns in response to PRO differs in two ways from the pattern found for pronouns. 1) For PRO, it appears that referents are reactivated in right-to-left fashion, while there was simultaneous activation of potential antecedents of the pronoun; 2) There was no significant activation of an antecedent for PRO until a position 1000 msec. after the initial probe. Unlike the ambiguity in structure of the passive construction, which could account for the lag in the reactivation of an antecedent, these constructions are not ambiguous. It is unclear why there should be this difference in the time course of reactivation patterns in response to pronouns vs. PRO. There are obvious differences between the two NP types, in terms of
syntactic distribution, phonological realization, and constraints on coreference; yet it is not at all evident why such differences would give rise to this particular effect.
Summary of Experimental Results.

In the discussion so far, I have considered the reactivation patterns of previously-mentioned referents in response to different NP types. To summarize: results of on-line studies show that in sentences in which the grammar dictates a unique antecedent, there is immediate reactivation of only that antecedent, and in sentences where more than one referent may bind the referentially-dependent element, all such referents are re-accessed. Thus, wh-traces and overt anaphors immediately trigger reactivation of only the referent that must bind the antecedent, in accordance, in one instance, with the theory that all NPs must receive a theta role from the verb, and in the other case, in compliance with Binding theory. The finding that NP-traces in passive sentences do not exhibit this reactivation effect is viewed as being due to the ambiguity inherent in the passive construction. It was also found that, with respect to reactivation patterns, pronouns cluster with PRO: they both cause reactivation of multiple referents. Reactivation in response to pronouns obeys Binding Condition B: the subject of the clause in which the pronoun appears is not re-accessed. As for PRO, both potential antecedents are reactivated, and, in general, the actual antecedent of PRO is not predictable on the basis of structural information alone.

3.4 A MODEL OF THE COREFERENCE PROCESSOR.

The experiments reviewed here strongly support the view that the reactivation of prior referents is restricted by grammatical
constraints. Let us now consider these findings within the framework of the model proposed by Cowart and Cairns (1987). They suggest that there is a special-purpose mechanism, or module, that performs coreference operations. They distinguish what they call these "structural reference processes" from more general interpretative processes, and hypothesize that this device identifies candidate antecedents for a pronoun on the basis of purely structural information. Higher level processes, which have access to semantic and pragmatic knowledge, then operate to isolate the most appropriate antecedent from the candidate set. In support of this model, they provide the following evidence.

They created pairs of sentence fragments such as in (23)-(25)

23)  
   a. If they want to save money, visiting uncles...
   b. If they want to believe that visiting uncles...

24)  
   a. Even though they use very little oil, frying eggs...
   b. Even though they eat very little oil, frying eggs...

25)  
   a. Whenever they smile during the procedure, charming babies...
   b. Whenever they lecture during the procedure, charming babies...

Fragments such as those in (a) had been used in a previous experiment. These were constructed such that the first two words in the second clause were structurally ambiguous, analyzable as either gerund + noun or adjective + noun. These sentence fragments were presented auditorily to subjects. At the end of the fragment, either the word, "is", or the word, "are", was presented tachistoscopically, and subjects were asked to read this word aloud. (Note that "is" is compatible with the gerund + noun interpretation, while "are" is compatible with the adjective + noun interpretation. Response times (measured from the end of the fragment to the beginning of the subjects' vocalization) were recorded. Results showed that responses
to "are" were significantly faster than responses to "is". This suggests that the ambiguous expression was construed as an adjective + noun in order to provide the pronoun, "they" with a referent. Cowart and Cairns refer to this as the "Pronoun Bias Effect". In the second experiment, the (a) and (b) versions were compared. Each of the (b) versions was designed to be anomalous if "they" was coindexed with the ambiguous string. Yet each represents a different type of anomaly: (23b) violates syntactic constraints (Binding Condition C), (24b) violates selectional restrictions (i.e. the verb requires an animate subject), and (25c) violates conditions on plausibility.

The results demonstrate that the Pronoun Bias Effect obtains in the (b) sentences only when violations concern selectional restrictions and pragmatics (i.e. in (24b) and (25b)), and not in sentences such as (23b), in which syntactic constraints would be violated.

These findings are fully consistent with the results reported in the review above. First, syntactic constraints restrict coreference of a referentially-dependent NP and an antecedent. In the studies above, such constraints acted to restrict reactivation of prior referents; here, they prevent coreference between a pronoun and an r-expression when coreference would violate Condition C. Second, the studies described above indicate in several instances that pragmatic factors appear to play no role in restricting the activation of multiple referents. Further, the study by Garnsey et al., and Nicol and Osterhout (1988) showed that the implausibility of an antecedent of wh-trace did not prevent it from being reactivated in response to the trace. In the Cowart and Cairns study,
coreference is established between the pronoun and a subsequent potential antecedent despite the fact that this results in pragmatic anomaly.

On the basis of their findings, Cowart and Cairns argue that there is a device which computes coreference, and that this device has access to structural information, but not to what is often considered to be "higher level" information, such as semantics and pragmatics, information that is normally quite useful in establishing coreference relations. They suggest that coreference assignment is a two-stage process in which candidates are isolated in accordance with syntactic principles, and these are selected or replaced as dictated by semantics and real-world knowledge. Their results support a language processing system which is essentially modular in nature: the sentence processor consists of subprocessors which have access to certain types of information and not others, and the flow of information is constrained such that processes that operate on structure may provide input to interpretative processes but not vice versa.

I propose that the coreference module constitutes an intermediate stage (perhaps one of many) between purely structural processes and interpretative processes. Within this model, the parser is a device which is dedicated only to building the structural representation of a sentence. The parser has available to it information concerning legitimate phrase structure, argument/non-argument positions, and the theta criterion. Lexical access routines supply the parser with information about the grammatical category of particular lexical items, and subcategorization properties (see
Chapter 1, for further discussion of these issues). The parser provides input to the coreference device; hence, the coreference processor has access to this body of information in addition to constraints on binding. Thus, presented with a parse-tree, and applying information concerning valid coreference relations, the coreference device determines which referents are potential antecedents of a referentially-dependent item, and accesses only those referents. This candidate set of referents may then be examined by higher level processes, and the most appropriate referent selected as the antecedent.

This account may be further elaborated. There is evidence that, in addition to constraints on binding and other relevant structural information, the coreference processor has access to a restricted class of semantic information that enters crucially into the assignment of an antecedent to a pronoun: information concerning gender and number.

3.5 EMPRICAL EVIDENCE FOR SEMANTIC FEATURE CONSTRAINTS ON COREREFERENCE.

Pronouns (and anaphors) contain little semantic content except for basic semantic features: number, gender, and "humanness". A non-syntactic constraint on the assignment of antecedence to a pronoun is that a pronoun and an antecedent must match along these dimensions. (This applies also to anaphors, however, since the antecedent of an anaphor is dictated in any case by binding constraints, anaphor cases will not be discussed.) So, for example, while the sentence, "John told Bill that he should get the
promotion." is ambiguous with respect to the identity of the pronoun, the ambiguity disappears if "Bill" is replaced with "Mary": "John told Mary that he should get the promotion". Compare also the coreference relations within the following two sentences: "Mary drove the car home just after the accident, and John examined her carefully"; "Mary drove the car home just after the accident, and John examined it carefully." Information of this kind would obviously be extremely useful to the coreference processor in limiting the initial candidate set of antecedents. Yet such information is semantic in nature, and the evidence suggests that semantics are not involved in the early processing of coreference. These particular features, however, plausibly form a privileged semantic class, and thus it is reasonable to suppose that they may be available to the coreference device. There is, in fact, empirical evidence that suggests that the coreference processor does indeed have access to this type of information.

MacDonald (1988) found evidence for the early use of gender information. Using a cross-modal probe verification task (i.e. auditory presentation of sentences with a visually-presented probe word that had either occurred previously in the sentence or not), she measured response times to probes in sentence pairs such as (26):

26) a. After this speech, Carol will easily beat Burt in the election, and she is expecting an early victory.

b. After this speech, Carol will easily beat Burt in the election, and all the supporters are sensing victory.

There were three probe points: just after the pronoun (or its nonpronoun counterpart, such as "all" in (26b)), and at points 250 msec. and 500 msec. downstream from this position. Probing for
both referents, she found differential facilitation for the two referents at the second of the three probe points. Specifically, she found priming for the actual antecedent, and inhibition of the other referent. This data suggests that gender information may be available relatively early on in the processing of such sentences.

Using the cross-modal priming task, Nicol (see Chapter 2) examined the availability of both gender and number information during on-line sentence comprehension. Priming for the first and second NP was measured at the offset of the pronoun in sentences such as (27) and (28). Experimental sentences were adapted from the pronoun/anaphor study described above (cf. (19)).

27) a. The boxer₁ told the skiers that the doctor for the team would blame him₁ # for the recent injury.

   b. The boxer told the skiers₁ that the doctor for the team would blame them₁ # for the recent injury.

28) a. The ballerina₁ told the skier that the doctor for the team would blame her₁ # for the recent injury.

   b. The ballerina told the skier₁ that the doctor for the team would blame him₁ # for the recent injury.

In the sentences pairs that contain the number contrast, the pronoun in the embedded clause was either singular or plural, and the first and second NPs were also either singular or plural. The sentence pairs in which gender was contrasted were similarly balanced.

There are two clear predictions. If number and gender information does not constrain the coreference device, then one would expect essentially the same results as were obtained for the pronoun/anaphor study: reactivation of both referents. However, if it does play a role, then there ought to be differential activation
of antecedents. Shown below are the results (magnitude of priming) for cases in which number or gender value for the referent and the pronoun either match or mismatch:

<table>
<thead>
<tr>
<th>Type of Pronoun</th>
<th>Referent</th>
<th>Singular</th>
<th>Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Singular</td>
<td>32*</td>
<td>-6</td>
</tr>
<tr>
<td></td>
<td>Plural</td>
<td>-13</td>
<td>42*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Pronoun</th>
<th>Referent</th>
<th>Feminine</th>
<th>Masculine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feminine</td>
<td>36*</td>
<td>-8</td>
</tr>
<tr>
<td></td>
<td>Masculine</td>
<td>48*</td>
<td>45*</td>
</tr>
</tbody>
</table>

The results for the singular/plural referents are quite straightforward. There is priming only for those referents that match in number with the pronoun. This clearly indicates that number information acts to restrict which referents will be re-accessed once a pronoun has been encountered, and supports the Cowart and Cairns results presented above.

The priming data for the gender study, however, are less clear. In this study, only the masculine pronoun exhibits differential priming of referents. The feminine pronoun appears to evoke both referents. This pattern, however, may reflect a property of the actual nouns that were used in this study, rather than a general feature of gender processing. In the majority of instances, the feminine referents are marked as feminine. In two-thirds of the cases (sixteen out of twenty-four), the noun contains a feminine suffix (usually "-ess", as in "waitress"); the rest are not overtly marked, yet are most often inherently female, such as "bride" and
"nun". Hence, in the sentences containing the masculine pronoun, "him", a referent such as "stewardess" will not be reactivated, but a more neutral referent such as "skier" will. On the other hand, the feminine pronoun, "her" will reactivate both the obviously female referent and the other referent. On this account, one would expect that using only inherently masculine referents such as "king", and "boy scout" would eliminate the asymmetry of the data, and that results would exhibit the same pattern as found for the singular/plural study.

Overall, these results support the notion that number and gender information is available to the coreference device. It remains to be seen whether or not "humanness" information is also available. Given that pronouns and antecedents must match for this feature also, one would expect the coreference processor to have access to it. There are two findings that offer apparent counter-evidence. Recall that Cowart and Cairns found that the Pronoun Bias Effect persisted even in sentences in which selection restrictions were violated: coindexing the pronoun in the first clause with the expression in the second clause yielded sentences such as, "Even though they eat little oil, frying eggs...", which conveys that "eggs eat little oil". In addition, Nicol and Osterhout (1988) found that the [+human] antecedent of an erroneously postulated wh-trace is reactivated following verbs that normally only take nonhuman complements, as in "That's the actress that the dentist planned to..." (cf. "That's the trip that the dentist planned to..."). The first example shows incongruence between a subject and its verb; the second between a verb and its object. Mismatches of this type,
however, are different in kind from mismatches between an antecedent and pronoun. The function that a pronoun serves is to reintroduce a previously-mentioned NP: the matching of features reduces the likelihood of ambiguity. Consider now the subject-verb or verb-object cases. First, such pairs of items cannot be said to "match" or "mismatch" in features in the same way that two coreferring NPs do; it is unlikely that "plan", a verb, would itself contain a feature such as [+/- human], though the verb could be marked as requiring its arguments to bear this feature. Even in this case, however, incongruence merely leads to local incoherence; mismatching features in no way make processing easier. Further, it would be bizarre to suppose that there might be a special-purpose device that checks such features, and only such features, for congruence. More likely, feature-matching across these constituents is handled by higher-level processes. In short, the fact that coreference processes ignore information about humanness in these two instances has no bearing on whether or not the coreference device is able to use such information to establish coreference between a pronoun and its antecedent.

These experiments demonstrate that the coreference device has access to a special class of semantic information that is crucial for linking a pronoun to a particular antecedent: number and gender.

3.6 CONCLUSIONS.

Taken together, the findings presented in the above section, and the results reviewed earlier demonstrate that the coreference device has access to the following: 1) information concerning
grammatical category; 2) syntactic constraints on coreference (including relevant information regarding structural position, as well as the theta criterion); and 3) the semantic features carried by pronouns that must match those of the antecedent.
--- Notes ---

1. Condition A is more commonly formulated as: "An anaphor must be bound in its governing category". The term "governing category" is defined to capture both the condition on locality and the condition on c-command relations, as well as the constraint that the anaphor must be "governed". For the purposes of this paper, the formulation of Condition A in (5) is sufficient.

2. Even if such information were available earlier, we do not believe that the parser is able to make use of this information at all during the initial parse of a sentence; on our view, the parser has access only to information relating to structure.

3. It may be fruitful to test a structure such as the following: "The woman has children to feed t." While the precise syntactic analysis of such sentences is not uncontroversial, the object of "feed" in this case is clearly "children".
REFERENCES


Cloitre, M. and Bever, T.G. Pronouns and noun anaphors access distinct levels of representation during discourse processing.


APPENDICES

There are three appendices. The first two contain the entire set of stimulus materials for Experiment 1.1, and for Experiment 2.1. All probe points are indicated with the symbol: ^. Above each probe point, the target item for that sentence is printed in upper case. All experimental sentences are prefixed with an "E"; all practice trials with a "P". Targets for experimental sentences are coded as: R1 (related to referent 1); U1 (unrelated to referent 1); R2 (related to referent 2); and U2 (unrelated to referent 2). Both versions of each experimental sentence are provided. Each experimental sentence in Exp 1.1 is given once for each target associated with it; hence, each version of a particular experimental sentence is given eight times. The order of presentation coincides with target lists; the target in E2a, for example, appeared in list A. However, the notation e-h translates as: tape 2, lists a-d. So, the target for E2e appears in list A, but sentence E2e is associated with Tape 2. Both versions of experimental sentences for Experiment 2.1 are collapsed into one which contains both anaphoric elements in the embedded clause. The order of these elements in a particular sentence corresponds to Tapes 1 and 2. Again, the order of sentences reflects membership of the target with a list: E2a, for example, contains a target that appeared in list A. The third appendix contains only experimental sentences for Exp. 2.3; filler sentences were identical to those in 2.1. All notation for these materials is the same as for 2.1. (Materials for Experiments 1.2 and 2.2 are not provided, since they are derivative of materials in 1.1 and 2.1, respectively.)
APPENDIX A

STIMULUS MATERIALS FOR EXPERIMENT 1.1

SWEET

P1. After the robbery, a locksmith was called in to change all the locks in the house.

P2. It's the man in the wool sweater who was kind enough to take in the TACK sick dog that had been abandoned by its owner.

BELLO

P3. A city clerk attended to the old man in the office, even though it was her lunch hour.

CREST

P4. It's the secretary in the front office who's perfectly fluent in Spanish and French.

P5. What the couple found so appealing about the restaurant was its SMATTY quiet elegance and understated decor.

MUBE

P6. The dean of the university introduced the visiting scientist to the prize-winning novelist at the reception that was held in the writer's honor.

HAIR

P7. The grandmother of the five children had spent the entire day cleaning the house in preparation for their visit.

P8. It was the cleaning lady who found the gardener unconscious after MIRROR he had had a heart attack.

ELLODE

P9. After having lunch with the countess, the earl from Cornwall asked his private secretary to send her a dozen roses.

VOE

P10. What startled the cleaning lady about seeing the young man dressed in the army uniform was how much he resembled his father.

CENTURY

P11. The manager of the supermarket had hired the teenager to deliver groceries after hearing how desperately she needed the extra money.

P12. The potter donated thirty-six ceramic mugs to the church to be sold WICE in the upcoming craft fair.
1. The presidential candidate had been forced to withdraw from the race when it was discovered that he had once been affiliated with a neo-Nazi organization.

E2a. Here is the baker that the actor who had just moved into the area CAKE (RI) had hired t PRO to ^ speak to the butler.

E2b. Here is the baker that the actor who had just moved into the area MOVIE (R2) had hired t PRO to ^ speak to the butler.

E2c. Here is the baker that the actor who had just moved into the area BOLT (U1) had hired t PRO to ^ speak to the butler.

E2d. Here is the baker that the actor who had just moved into the area PANEL (U2) had hired t PRO to ^ speak to the butler.

E2e. Here is the baker that the actor who had just moved into the area CAKE (RI) had intended PRO to ^ speak to the butler about t.

E2f. Here is the baker that the actor who had just moved into the area MOVIE (R2) had intended PRO to ^ speak to the butler about t.

E2g. Here is the baker that the actor who had just moved into the area BOLT (U1) had intended PRO to ^ speak to the butler about t.

E2h. Here is the baker that the actor who had just moved into the area PANEL (U2) had intended PRO to ^ speak to the butler about t.

3. Before seeing the patient, ^ the psychiatrist read carefully through the records that had been sent over to him from the institution.

4. It was the teenager in the striped shirt that sought help after the ARP child had been hit ^ by a car.

TIBA

5. The committee on environmental protection met over ^ the weekend to discuss the proposal to build a dam on the lake just outside town.

E6a. That's the doctor that the queen of the small country in West NURSE (R1) Africa had implored t PRO to ^ discuss the clinic.
E6b. That's the doctor that the queen of the small country in West KING (R2)
Africa had implored t PRO to ^ discuss the clinic.

E6c. That's the doctor that the queen of the small country in West LODGE (U1)
Africa had implored t PRO to ^ discuss the clinic.

E6d. That's the doctor that the queen of the small country in West BASE (U2)
Africa had implored t PRO to ^ discuss the clinic.

E6e. That's the doctor that the queen of the small country in West NURSE (R1)
Africa had declined PRO to ^ discuss the clinic with t.

E6f. That's the doctor that the queen of the small country in West KING (R2)
Africa had implored t PRO to ^ discuss the clinic.

E6g. That's the doctor that the queen of the small country in West LODGE (U1)
Africa had implored t PRO to ^ discuss the clinic.

E6h. That's the doctor that the queen of the small country in West BASE (U2)
Africa had implored t PRO to ^ discuss the clinic.

STOL

7. While the couple was vacationing in Italy, they ran into ^ some old friends that they hadn't seen in five years.

8. What the lab really needed was a new photocopier to replace the one dog
that ^ broke down last month.

E9a. That's the photographer that the reporter working free-lance for CAMERA (R1)
the new agency had selected t PRO to ^ help out with the assignment.

E9b. That's the photographer that the reporter working free-lance for PAPER (R2)
the new agency had selected t PRO to ^ help out with the assignment.

E9c. That's the photographer that the reporter working free-lance for MUSEUM (U1)
the new agency had selected t PRO to ^ help out with the assignment.

E9d. That's the photographer that the reporter working free-lance for LABOR (U2)
the new agency had selected t PRO to ^ help out with the assignment.

E9e. That's the photographer that the reporter working free-lance for CAMERA (R1)
the new agency had struggled PRO to ^ help out t with the assignment.

- 137 -
E9f. That's the photographer that the reporter working free-lance for 
PAPER (R2) 
the new agency had struggled PRO to ^ help out t with the assignment.

E9g. That's the photographer that the reporter working free-lance for 
MUSEUM (U1) 
the new agency had struggled PRO to ^ help out t with the assignment.

E9h. That's the photographer that the reporter working free-lance for 
LABOR (U2) 
the new agency had struggled PRO to ^ help out t with the assignment.

RANDE

10. The curator at the ^ art museum was delighted to discover that the 
famous exhibit would be coming to his museum.

11. It was the evening newscaster who had investigated the congressman's 
IFER 
activities and revealed the ^ details to the public.

MILD

12. The firefighter was recently congratulated ^ by the mayor for 
rescuing the woman and her children.

E13a. Here is the student that the banker who always enjoyed a good 
CLASS (R1) 
murder mystery had advised t PRO to ^ see the play at the theatre.

E13b. Here is the student that the banker who always enjoyed a good 
MONEY (R2) 
murder mystery had advised t PRO to ^ see the play at the theatre.

E13c. Here is the student that the banker who always enjoyed a good 
FIELD (U1) 
murder mystery had advised t PRO to ^ see the play at the theatre.

E13d. Here is the student that the banker who always enjoyed a good 
LOCAL (U2) 
murder mystery had advised t PRO to ^ see the play at the theatre.

E13e. Here is the student that the banker who always enjoyed a good 
CLASS (R1) 
murder mystery had agreed PRO to ^ see the play at the theatre with t.

E13f. Here is the student that the banker who always enjoyed a good 
MONEY (R2) 
murder mystery had agreed PRO to ^ see the play at the theatre with t.

E13g. Here is the student that the banker who always enjoyed a good 
FIELD (U1) 
murder mystery had agreed PRO to ^ see the play at the theatre with t.

E13h. Here is the student that the banker who always enjoyed a good 
LOCAL (U2) 
murder mystery had agreed PRO to ^ see the play at the theatre with t.
14. The council member from Chicago arranged for the committee to meet CINILANY
to discuss the city's drug problems.

15. One of the flight attendants was asked to look after a ten year POICH
child travelling alone on the flight from Denver to San Francisco.

El6a. This is the lawyer that the stewardess who was recently fired from COURT (R1)
her job had convinced t PRO to ^ discuss the case.

El6b. This is the lawyer that the stewardess who was recently fired from PLANE (R2)
her job had convinced t PRO to ^ discuss the case.

El6c. This is the lawyer that the stewardess who was recently fired from FRONT (U1)
her job had convinced t PRO to ^ discuss the case.

El6d. This is the lawyer that the stewardess who was recently fired from SCENE (U2)
her job had convinced t PRO to ^ discuss the case.

El6e. This is the lawyer that the stewardess who was recently fired from COURT (R1)
her job had planned PRO to ^ discuss the case with t.

El6f. This is the lawyer that the stewardess who was recently fired from PLANE (R2)
her job had planned PRO to ^ discuss the case with t.

El6g. This is the lawyer that the stewardess who was recently fired from FRONT (U1)
her job had planned PRO to ^ discuss the case with t.

El6h. This is the lawyer that the stewardess who was recently fired from SCENE (U2)
her job had planned PRO to ^ discuss the case with t.

17. Before going to Morocco, the businessman from Dallas had been FLAL
vaccinated against typhoid and malaria.

MAPLE

18. What the manager hoped to discuss with her employer was the possibility of a transfer to the west coast.

ATLAS

19. To celebrate their parents' 25th wedding anniversary the children organized a surprise party.
20. The receptionist at the large firm was unhappy with her work so she decided to enroll in business school.

E21a. That’s the waitress that the senator who was always involved in some scandal had forced PRO to leave the country.

E21b. That’s the waitress that the senator who was always involved in some scandal had forced PRO to leave the country.

E21c. That’s the waitress that the senator who was always involved in some scandal had forced PRO to leave the country.

E21d. That’s the waitress that the senator who was always involved in some scandal had forced PRO to leave the country.

E21e. That’s the waitress that the senator who was always involved in some scandal had attempted PRO to leave the country with t.

E21f. That’s the waitress that the senator who was always involved in some scandal had attempted PRO to leave the country with t.

E21g. That’s the waitress that the senator who was always involved in some scandal had attempted PRO to leave the country with t.

E21h. That’s the waitress that the senator who was always involved in some scandal had attempted PRO to leave the country with t.

IMAND

22. In order to repair the toaster, the electrician had to send away for parts from the head company in Nebraska.

23. The baseball player was forced to retire when he was caught using drugs.

E24a. There’s the duke that the judge on vacation for several weeks had had advised PRO to go to the opera.

E24b. There’s the duke that the judge on vacation for several weeks had had advised PRO to go to the opera.

E24c. There’s the duke that the judge on vacation for several weeks had had advised PRO to go to the opera.
E24d. There's the duke that the judge on vacation for several weeks had
ISSUE (U2)
had advised t PRO to ^ go to the opera.

E24e. There's the duke that the judge on vacation for several weeks had
KING (R1)
had hoped PRO to ^ go to the opera with t.

E24f. There's the duke that the judge on vacation for several weeks had
TRIAL (R2)
had hoped PRO to ^ go to the opera with t.

E24g. There's the duke that the judge on vacation for several weeks had
BASE (U1)
had hoped PRO to ^ go to the opera with t.

E24h. There's the duke that the judge on vacation for several weeks had
ISSUE (U2)
had hoped PRO to ^ go to the opera with t.

25. What the little girl most wanted for her birthday was a trip to the
BLOIPOM
zoo and dinner at the ^ restaurant down the street.

MORIF
26. The principal ^ of the high school was upset by the disrespectful
manner in which many of the students treated the teachers.

E27a. That's the plumber that the tailor from the shop on the outskirts
PIPE (R1)
of town had hired t PRO to ^ work on the project.

E27b. That's the plumber that the tailor from the shop on the outskirts
SEW (R2)
of town had hired t PRO to ^ work on the project.

E27c. That's the plumber that the tailor from the shop on the outskirts
LAMP (U1)
of town had hired t PRO to ^ work on the project.

E27d. That's the plumber that the tailor from the shop on the outskirts
DIP (U2)
of town had hired t PRO to ^ work on the project.

E27e. That's the plumber that the tailor from the shop on the outskirts
PIPE (R1)
of town had begun PRO to ^ work on the project with t.

E27f. That's the plumber that the tailor from the shop on the outskirts
SEW (R2)
of town had begun PRO to ^ work on the project with t.
E27g. That's the plumber that the tailor from the shop on the outskirts
LAMP (U1)
of town had begun PRO to ^ work on the project with t.

E27h. That's the plumber that the tailor from the shop on the outskirts
DIP (U2)
of town had begun PRO to ^ work on the project with t.

FUEL
28. The young governess brought ^ a bag full of toys and comic books in
case the children got bored at the family reunion.

DRIG
29. After eight days of deliberation, ^ the jury finally reached a
verdict.

CLOVER
30. It was the sudden increase in video rentals that ^ finally forced
the owner of the movie theater to shut down.

E31a. This is the swimmer that the girl who was visiting San Diego,
DIVE (R1)
California had urged t PRO to ^ practice for the games.

E31b. This is the swimmer that the girl who was visiting San Diego,
BOY (R2)
California had urged t PRO to ^ practice for the games.

E31c. This is the swimmer that the girl who was visiting San Diego,
HERD (U1)
California had urged t PRO to ^ practice for the games.

E31d. This is the swimmer that the girl who was visiting San Diego,
JOB (U2)
California had urged t PRO to ^ practice for the games.

E31e. This is the swimmer that the girl who was visiting San Diego,
DIVE (R1)
California had aspired PRO to ^ practice for the games with t.

E31f. This is the swimmer that the girl who was visiting San Diego,
BOY (R2)
California had aspired PRO to ^ practice for the games with t.

E31g. This is the swimmer that the girl who was visiting San Diego,
HERD (U1)
California had aspired PRO to ^ practice for the games with t.

E31h. This is the swimmer that the girl who was visiting San Diego,
JOB (U2)
California had aspired PRO to ^ practice for the games with t.

32. What the executive secretary needed more than a new typewriter was
BROWN
a computer with ^ a good word processor.
33. The wealthy customer angrily sent back the bottle of Bordeaux, claiming that the wine had spoiled.

34. The golf pro missed his chance at winning the open due to a broken wrist.

E35a. There's the maid that the general who was always strict with his SERVANT (R1) staff had permitted PRO to ^ have dinner.

E35b. There's the maid that the general who was always strict with his ARMY (R2) staff had permitted PRO to ^ have dinner.

E35c. There's the maid that the general who was always strict with his PACKAGE (U1) staff had permitted PRO to ^ have dinner.

E35d. There's the maid that the general who was always strict with his EASY (U2) staff had permitted PRO to ^ have dinner.

E35e. There's the maid that the general who was always strict with his SERVANT (R1) staff had refused PRO to ^ have dinner with t.

E35f. There's the maid that the general who was always strict with his ARMY (R2) staff had refused PRO to ^ have dinner with t.

E35g. There's the maid that the general who was always strict with his PACKAGE (U1) staff had refused PRO to ^ have dinner with t.

E35h. There's the maid that the general who was always strict with his EASY (U2) staff had refused PRO to ^ have dinner with t.

36. The clown with the orange hair volunteered to come ^ into the hospital once a month to entertain the children on the 14th floor.

E37a. That's the cook that the minister from the town on the other side CHEF (R1) of the lake had trusted PRO to ^ help out at the picnic.

E37b. That's the cook that the minister from the town on the other side SERMON (R2) of the lake had trusted PRO to ^ help out at the picnic.
E37c. That's the cook that the minister from the town on the other side of the lake had trusted t PRO to help out at the picnic.

E37d. That's the cook that the minister from the town on the other side of the lake had trusted t PRO to help out at the picnic.

E37e. That's the cook that the minister from the town on the other side of the lake had begun PRO to help out t at the picnic.

E37f. That's the cook that the minister from the town on the other side of the lake had begun PRO to help out t at the picnic.

E37g. That's the cook that the minister from the town on the other side of the lake had begun PRO to help out t at the picnic.

E37h. That's the cook that the minister from the town on the other side of the lake had begun PRO to help out t at the picnic.

38. It was the long summer vacations that the former school teacher missed the most when he started working for the firm.

39. After receiving a degree in agriculture, the young man with brown hair decided to join the Peace Corps and go abroad.

40. The clothing designer was still a novice when she designed the prize-winning silk gown.

E41a. Here is the mechanic that the salesman who was recently commissioned by the large company had permitted t PRO to work on the equipment.

E41b. Here is the mechanic that the salesman who was recently commissioned by the large company had permitted t PRO to work on the equipment.

E41c. Here is the mechanic that the salesman who was recently commissioned by the large company had permitted t PRO to work on the equipment.

E41d. Here is the mechanic that the salesman who was recently commissioned by the large company had permitted t PRO to work on the equipment.
E41e. Here is the mechanic that the salesman who was recently FIX (R1)
commissioned by the large company had refused PRO to ^ work on
the equipment with t.

E41f. Here is the mechanic that the salesman who was recently SELL (R2)
commissioned by the large company had refused PRO to ^ work on
the equipment with t.

E41g. Here is the mechanic that the salesman who was recently DOT (U1)
commissioned by the large company had refused PRO to ^ work on
the equipment with t.

E41h. Here is the mechanic that the salesman who was recently PATH (U2)
commissioned by the large company had refused PRO to ^ work on
the equipment with t.

42. Several illegal aliens were apprehended by the police when their MAGGE
van ^ was hit by a truck.

43. The boys were disappointed that the large ^ number of jelly-fish in
the waters off the coast of Maryland made swimming impossible.

E44a. This is the singer that the duchess celebrating her return to the SONG (R1)
south of England had allowed t PRO to ^ perform at the party.

E44b. This is the singer that the duchess celebrating her return to the DUKE (R2)
south of England had allowed t PRO to ^ perform at the party.

E44c. This is the singer that the duchess celebrating her return to the FLOW (U1)
south of England had allowed t PRO to ^ perform at the party.

E44d. This is the singer that the duchess celebrating her return to the HINT (U2)
south of England had allowed t PRO to ^ perform at the party.

E44e. This is the singer that the duchess celebrating her return to the SONG (R1)
south of England had decided PRO to ^ perform at the party with t.

E44f. This is the singer that the duchess celebrating her return to the DUKE (R2)
south of England had decided PRO to ^ perform at the party with t.

E44g. This is the singer that the duchess celebrating her return to the FLOW (U1)
south of England had decided PRO to ^ perform at the party with t.
E44h. This is the singer that the duchess celebrating her return to the HINT (U2) south of England had decided PRO to ^ perform at the party with t.

GONTH

45. What was puzzling about this case was that ^ the prime suspect had no apparent motive for murdering the employer.

E46a. There's the nun that the teacher who had just received her PRAY (R1) certificate had urged t PRO to ^ lecture to the class.

E46b. There's the nun that the teacher who had just received her PUPIL (R2) certificate had urged t PRO to ^ lecture to the class.

E46c. There's the nun that the teacher who had just received her BARK (U1) certificate had urged t PRO to ^ lecture to the class.

E46d. There's the nun that the teacher who had just received her GIANT (U2) certificate had urged t PRO to ^ lecture to the class.

E46e. There's the nun that the teacher who had just received her PRAY (R1) certificate had planned PRO to ^ lecture to the class about t.

E46f. There's the nun that the teacher who had just received her PUPIL (R2) certificate had planned PRO to ^ lecture to the class about t.

E46g. There's the nun that the teacher who had just received her BARK (U1) certificate had planned PRO to ^ lecture to the class about t.

E46h. There's the nun that the teacher who had just received her GIANT (U2) certificate had planned PRO to ^ lecture to the class about t.

47. The star basketball player agreed to endorse the new line of HOOST running shoes, ^ even though he didn't think they were very durable or well-made.

OMPORE

48. Due to the prolonged drought in the area, ^ crops were ruined and many animals died.

FLIDE

49. The company has hired the contractor recommended ^ by the architect to build the new apartment complex by the end of the year.
E50a. There is the burglar that the farmer from a small community in western Idaho had ordered \text{ PRO to leave} on the next train.

E50b. There is the burglar that the farmer from a small community in western Idaho had ordered \text{ PRO to leave} on the next train.

E50c. There is the burglar that the farmer from a small community in western Idaho had ordered \text{ PRO to leave} on the next train.

E50d. There is the burglar that the farmer from a small community in western Idaho had ordered \text{ PRO to leave} on the next train.

E50e. There is the burglar that the farmer from a small community in western Idaho had schemed \text{ PRO to leave} on the next train with \text{ t}.

E50f. There is the burglar that the farmer from a small community in western Idaho had schemed \text{ PRO to leave} on the next train with \text{ t}.

E50g. There is the burglar that the farmer from a small community in western Idaho had schemed \text{ PRO to leave} on the next train with \text{ t}.

E50h. There is the burglar that the farmer from a small community in western Idaho had schemed \text{ PRO to leave} on the next train with \text{ t}.

CALL

51. What the flight attendant had forgotten to take with her \text{ was the small leather bag she'd bought in Italy.}

NAND

52. After 30 years on \text{ the job}, the typist in the manager's office was planning to retire at the end of the month, one week after her 60th birthday.

REIMIN

53. During the blizzard, the children stayed indoors, drinking \text{ hot chocolate} and playing cards.

E54a. This is the electrician that the policeman from the department concerned with housing had persuaded \text{ PRO to look} for an apartment.

E54b. This is the electrician that the policeman from the department concerned with housing had persuaded \text{ PRO to look} for an apartment.
E54c. This is the electrician that the policeman from the department concerned with housing had persuaded t PRO to ^ look for an apartment.

E54d. This is the electrician that the policeman from the department concerned with housing had persuaded t PRO to ^ look for an apartment.

E54e. This is the electrician that the policeman from the department concerned with housing had intended PRO to ^ look for an apartment with t.

E54f. This is the electrician that the policeman from the department concerned with housing had intended PRO to ^ look for an apartment with t.

E54g. This is the electrician that the policeman from the department concerned with housing had intended PRO to ^ look for an apartment with t.

E54h. This is the electrician that the policeman from the department concerned with housing had intended PRO to ^ look for an apartment with t.

55. It was at the dinner party that the hostess announced her ^ engagement to the count.

56. The owner of ^ the wine store was planning a trip to France, which included a visit to the Champagne region, and tours of several reputable wineries.

E57a. There is the actress that the dentist from the new medical center in town had invited t PRO to ^ go to the party.

E57b. There is the actress that the dentist from the new medical center in town had invited t PRO to ^ go to the party.

E57c. There is the actress that the dentist from the new medical center in town had invited t PRO to ^ go to the party.

E57d. There is the actress that the dentist from the new medical center in town had invited t PRO to ^ go to the party.
E57e. There is the actress that the dentist from the new medical center STAGE (R1)
in town had hoped PRO to go to the party with t.

E57f. There is the actress that the dentist from the new medical center TOOTH (R2)
in town had hoped PRO to go to the party with t.

E57g. There is the actress that the dentist from the new medical center SPACE (U1)
in town had hoped PRO to go to the party with t.

E57h. There is the actress that the dentist from the new medical center FLOOD (U2)
in town had hoped PRO to go to the party with t.

58. The debutante was looking forward to the ball at the end of the ITRAT
summer and spent several ^ weeks deciding on a suitable dress for
the occasion.

E59a. That is the tenant that the janitor of the large apartment LEASE (R1)
building next door had bribed t PRO to fix the leaky faucet.

E59b. That is the tenant that the janitor of the large apartment CLEAN (R2)
building next door had bribed t PRO to fix the leaky faucet.

E59c. That is the tenant that the janitor of the large apartment BLOOM (U1)
building next door had bribed t PRO to fix the leaky faucet.

E59d. That is the tenant that the janitor of the large apartment SCORE (U2)
building next door had bribed t PRO to fix the leaky faucet.

E59e. That is the tenant that the janitor of the large apartment LEASE (r1)
building next door had tried PRO to fix the leaky faucet for t.

E59f. That is the tenant that the janitor of the large apartment CLEAN (R2)
building next door had tried PRO to fix the leaky faucet for t.

E59g. That is the tenant that the janitor of the large apartment BLOOM (U1)
building next door had tried PRO to fix the leaky faucet for t.

E59h. That is the tenant that the janitor of the large apartment SCORE (U2)
building next door had tried PRO to fix the leaky faucet for t.
GLUDEN

60. What was missing from the vault was an antique necklace worth hundreds of thousands of dollars.

LYCCOS

61. Although generally unaafraid of heights, the window washer had been frightened the first time he was assigned to the 30 story building.

E62a. Here's the chauffeur that the nurse who was stationed on the CAR (R1) seventh floor had invited t PRO to go out dancing.

E62b. Here's the chauffeur that the nurse who was stationed on the HOSPITAL (R2) seventh floor had invited t PRO to go out dancing.

E62c. Here's the chauffeur that the nurse who was stationed on the AIR (U1) seventh floor had invited t PRO to go out dancing.

E62d. Here's the chauffeur that the nurse who was stationed on the ATTITUDE (U2) seventh floor had invited t PRO to go out dancing.

E62e. Here's the chauffeur that the nurse who was stationed on the CAR (R1) seventh floor had hesitated PRO to go out dancing with t.

E62f. Here's the chauffeur that the nurse who was stationed on the HOSPITAL (R2) seventh floor had hesitated PRO to go out dancing with t.

E62g. Here's the chauffeur that the nurse who was stationed on the AIR (U1) seventh floor had hesitated PRO to go out dancing with t.

E62h. Here's the chauffeur that the nurse who was stationed on the ATTITUDE (U2) seventh floor had hesitated PRO to go out dancing with t.

DEBRY

63. When the couple saw the swimming pool in the back yard, they decided to make the owners an offer for the house.

RIG

64. What the author found so difficult about living in London were the long rainy winters.

E65a. There's the ballerina that the prince who was still single at age DANCE (R1) thirty-two had encouraged t PRO to marry while still young.
E65b. There's the ballerina that the prince who was still single at age CROWN (R2) thirty-two had encouraged t PRO to ^ marry while still young.

E65c. There's the ballerina that the prince who was still single at age BUILD (U1) thirty-two had encouraged t PRO to ^ marry while still young.

E65d. There's the ballerina that the prince who was still single at age DRAIN (U2) thirty-two had encouraged t PRO to ^ marry while still young.

E65e. There's the ballerina that the prince who was still single at age DANCE (R1) thirty-two had yearned PRO to ^ marry while still young.

E65f. There's the ballerina that the prince who was still single at age CROWN (R2) thirty-two had yearned PRO to ^ marry while still young.

E65g. There's the ballerina that the prince who was still single at age BUILD (U1) thirty-two had yearned PRO to ^ marry while still young.

E65h. There's the ballerina that the prince who was still single at age DRAIN (U2) thirty-two had yearned PRO to ^ marry while still young.

ABBADEN

66. One of the lifeguard's duties was ^ to make sure none of the young children at the swimming pool went into the deep without their parents.

SPORT

67. It was the Irish novelist who won the Pulitzer prize for ^ literature last year.

68. The star of the cowboy film was a man who grew up in the city and SIVULT has never ridden a horse until he had to audition for ^ the part in the movie.

E69a. This is the journalist that the detective who had been working NEWS (R1) behind the desk had encouraged t PRO to ^ call about the details of the story.

E69b. This is the journalist that the detective who had been working CRIME (R2) behind the desk had encouraged t PRO to ^ call about the details of the story.
E69c. This is the journalist that the detective who had been working behind the desk had encouraged t PRO to ^ call about the details of the story.

E69d. This is the journalist that the detective who had been working behind the desk had encouraged t PRO to ^ call about the details of the story.

E69e. This is the journalist that the detective who had been working behind the desk had attempted PRO to ^ call t about the details of the story.

E69f. This is the journalist that the detective who had been working behind the desk had attempted PRO to ^ call t about the details of the story.

E69g. This is the journalist that the detective who had been working behind the desk had attempted PRO to ^ call t about the details of the story.

E69h. This is the journalist that the detective who had been working behind the desk had attempted PRO to ^ call t about the details of the story.

70. As the tourists stepped off the plane in Hawaii, they were greeted by a group of local women in grass skirts.

BUPALL

71. The driving school instructor ^ was injured last week when one of his beginning student drove the car into a lamp post.

E72a. There is the sculptor that the heiress with the enormous estate just outside London had convinced t PRO to ^ go out to tea.

E72b. There is the sculptor that the heiress with the enormous estate just outside London had convinced t PRO to ^ go out to tea.

E72c. There is the sculptor that the heiress with the enormous estate just outside London had convinced t PRO to ^ go out to tea.

E72d. There is the sculptor that the heiress with the enormous estate just outside London had convinced t PRO to ^ go out to tea.
E72e. There is the sculptor that the heiress with the enormous estate
   just outside London had yearned PRO to ^ go out to tea with t.

E72f. There is the sculptor that the heiress with the enormous estate
   just outside London had yearned PRO to ^ go out to tea with t.

E72g. There is the sculptor that the heiress with the enormous estate
   just outside London had yearned PRO to ^ go out to tea with t.

E72h. There is the sculptor that the heiress with the enormous estate
   just outside London had yearned PRO to ^ go out to tea with t.

73. The senator's wife took her diamond ring to the jeweler to be ^
   appraised and discovered that it was worth $5000.

74. The sky-diver was asked to perform ^ several stunts at the annual
   air show held in July.

75. Of all the desserts at the restaurant, it was the ^ chocolate
   mousse that the customers seemed to prefer.

76. The dog-catcher was called by the frantic father whose son had just
   been ^ bitten by a stray dog.

E77a. Here's the artist that the nephew of the former president of the
   country had persuaded t PRO to ^ travel to the city.

E77b. Here's the artist that the nephew of the former president of the
   country had persuaded t PRO to ^ travel to the city.

E77c. Here's the artist that the nephew of the former president of the
   country had persuaded t PRO to ^ travel to the city.

E77d. Here's the artist that the nephew of the former president of the
   country had persuaded t PRO to ^ travel to the city.

E77e. Here's the artist that the nephew of the former president of the
   country had hesitated PRO to ^ travel to the city with t.

E77f. Here's the artist that the nephew of the former president of the
   country had hesitated PRO to ^ travel to the city with t.
E77g. Here's the artist that the nephew of the former president of the country had hesitated PRO to ^travel to the city with t.

E77h. Here's the artist that the nephew of the former president of the choir (U2) country had hesitated PRO to ^travel to the city with t.

IRSK

78. After hiring the local plumber for the job, ^the couple heard that he had a reputation for being unreliable and overcharging for materials.

79. It was the teller at the end of the counter who tried to sneak off boot ^with a wad of twenty-dollar bills.

E80a. That's the accountant that the writer who was doing a piece on corporate crime had induced t PRO to ^talk about the company.

E80b. That's the accountant that the writer who was doing a piece on story (R2) corporate crime had induced t PRO to ^talk about the company.

E80c. That's the accountant that the writer who was doing a piece on top (U1) corporate crime had induced t PRO to ^talk about the company.

E80d. That's the accountant that the writer who was doing a piece on hotel (U2) corporate crime had induced t PRO to ^talk about the company.

E80e. That's the accountant that the writer who was doing a piece on tax (R1) corporate crime had tried PRO to ^talk about the company to t.

E80f. That's the accountant that the writer who was doing a piece on story (R2) corporate crime had tried PRO to ^talk about the company to t.

E80g. That's the accountant that the writer who was doing a piece on top (U1) corporate crime had tried PRO to ^talk about the company to t.

E80h. That's the accountant that the writer who was doing a piece on hotel (U2) corporate crime had tried PRO to ^talk about the company to t.
APPENDIX B

STIMULUS MATERIALS FOR EXPERIMENT 2.1

TILE
P1. The lawyer advised the plastic surgeon to take out more malpractice insurance.

LAMP
P2. It was the old woman who complained to the police officer about the loud party at the house down the street.

P3. The owner of the restaurant offered the famous movie star a complimentary after dinner drink.

DEARD
P4. The anthropologist was pleased to accept the award from the president of the small third-world country.

P5. Throughout the circus performance, it was the acrobats who seemed to get the most applause from the audience.

UNIFORM
P6. It was eventually discovered by the rangers that the forest fire had been set by one of the park warden's children.

P7. Every summer the novelist left New York City to go to Cape Cod, where he owned a cottage by the beach.

P8. A bill was finally passed to limit the height of office buildings in the small downtown area.

DRACOT
P9. It was the fisherman from Seattle who won the prize last year for the largest salmon.

TABLET
P10. After the show, the cast went to the bar near the theater for drinks.

CARE
1. The car dealer was indicted on charges of false advertising after several customers had reported him to the Better Business Bureau.

E2a. The boxer told the skier that the doctor for the team would FIGHT(R1)
would probably blame him/himself for the recent injury.

E2b. The boxer told the skier that the doctor for the team would  
CLAIM(U1)  
would probably blame him/himself for the recent injury.

E2c. The boxer told the skier that the doctor for the team would  
SLOPE(R2)  
would probably blame him/himself for the recent injury.

E2d. The boxer told the skier that the doctor for the team would  
TOAST(U2)  
would probably blame him/himself for the recent injury.

E2e. The boxer told the skier that the doctor for the team would  
NURSE(R3)  
would probably blame him/himself for the recent injury.

E2f. The boxer told the skier that the doctor for the team would  
LODGE(U3)  
would probably blame him/himself for the recent injury.

BEACH

3. The young man in the blue shirt fainted the first time he volunteered to give blood.

4. Many of the guests at the party complimented the hostess on  
CREAB  
the beautiful flower arrangements.

E5a. The photographer told the reporter that the policeman  
MUSEUM(U1)  
in the blue uniform would protect himself/him if it became necessary.

E5b. The photographer told the reporter that the policeman  
CAMERA(R1)  
in the blue uniform would protect himself/him if it became necessary.

E5c. The photographer told the reporter that the policeman  
LABOR(U2)  
in the blue uniform would protect himself/him if it became necessary.

E5d. The photographer told the reporter that the policeman  
PAPER(R2)  
in the blue uniform would protect himself/him if it became necessary.

E5e. The photographer told the reporter that the policeman  
LOOP(U3)  
in the blue uniform would protect himself/him if it became necessary.
E5f. The photographer told the reporter that the policeman
in the blue uniform would protect himself/him if it became
necessary.

6. The new school librarian was disappointed with the poor
selection of reference books, and asked the
superintendent for a larger budget.

PE7. The ranger convinced the boy scout that the beekeeper in
the uniform would not let himself get stung by the bees.

CABLE
8. The movie theater prohibited smoking not only in the theater
itself, but also in the lobby.

E9a. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

E9b. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

E9c. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

E9d. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

E9e. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

E9f. The stewardess told the teller that the nurse with the
new car would teach her/herself how to drive this weekend.

10. The children's story was about a magician who lived in an
old castle at the edge of the dark forest.

MINNANG
11. Every year the accounting firm held a Christmas party for
its employees and their families.

PE12. The coach persuaded the runner that the chiropractor at
the clinic would help him recover from the accident.
13. Much to the dismay of the manager, the renowned chef quit his job at the hotel to open a restaurant of his own.

E14a. The artist told the journalist that the senator from California would buy himself/him the tickets to the performance.

E14b. The artist told the journalist that the senator from California would buy himself/him the tickets to the performance.

E14c. The artist told the journalist that the senator from California would buy himself/him the tickets to the performance.

E14d. The artist told the journalist that the senator from California would buy himself/him the tickets to the performance.

15. It was the next-door neighbor that had called for help when the teenager was hit by the truck last week.

16. The dog catcher was surprised to find the mayor's dog loose on the street.

E17a. The actress told the maid that the duchess from the country might introduce her/herself to the French Count.

E17b. The actress told the maid that the duchess from the country might introduce her/herself to the French Count.

E17c. The actress told the maid that the duchess from the country might introduce her/herself to the French Count.

E17d. The actress told the maid that the duchess from the country might introduce her/herself to the French Count.

E17e. The actress told the maid that the duchess from the country might introduce her/herself to the French Count.
E17f. The actress told the maid that the duchess from the HINT(U3) country might introduce her/herself ^ to the French Count.

BLANKET

18. During her last trip to Scotland, the clothing ^ designer bought fifty yards of fine wool.

PE19. The best man informed the organist that the family of the TRUG bride would pay him ^ for his services after the ceremony.

E20a. The archer told the golfer that the pilot in the blue DECAY(U1) uniform might introduce himself/him ^ to the beautiful movie star.

E20b. The archer told the golfer that the pilot in the blue ARROW(R1) uniform might introduce himself/him ^ to the beautiful movie star.

E20c. The archer told the golfer that the pilot in the blue HUM(U2) uniform might introduce himself/him ^ to the beautiful movie star.

E20d. The archer told the golfer that the pilot in the blue TEE(R2) uniform might introduce himself/him ^ to the beautiful movie star.

E20e. The archer told the golfer that the pilot in the blue VAN(U3) uniform might introduce himself/him ^ to the beautiful movie star.

E20f. The archer told the golfer that the pilot in the blue FLY(R3) uniform might introduce himself/him ^ to the beautiful movie star.

SUFFLER

21. The aging celebrity was disappointed that ^ the young people in the restaurant lounge did not seem to recognize him.

22. A fireman was honored today for saving three small children PHOSE who were ^ trapped in a burning apartment building.

GLASSES

23. What the lab needed most ^ was a new secretary to replace the one who had quit last month.
24. The old jeweller was the only one in town who was skilled in cutting precious stones.

E25a. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

E25b. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

E25c. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

E25d. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

E25e. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

E25f. The king told the priest that the general who was still overseas would not forgive him/himself for last week's disaster.

ENSILE

26. Every autumn, the old woman down the street picks cherries from the two cherry trees in her back yard and makes delicious pies for her friends.

E27a. The waitress told the princess that the nun from out of town would take care of herself/her during the holidays.

E27b. The waitress told the princess that the nun from out of town would take care of herself/her during the holidays.

E27c. The waitress told the princess that the nun from out of town would take care of herself/her during the holidays.

E27d. The waitress told the princess that the nun from out of town would take care of herself/her during the holidays.
E27e. The waitress told the princess that the nun from out of PRAY(R3)
town would take care of herself/her ^ during the holidays.

E27f. The waitress told the princess that the nun from out of BARK(U3)
town would take care of herself/her ^ during the holidays.

DURPET

28. In order to fix the washing machine, the repairman had ^ to
send away for parts from the head company in Ohio.

EMPINEER

29. After the rainstorm, the ^ bellboy told the old woman who
drove up in the taxi to watch her step getting out of the
cab.

PE30. The father told the pediatrician that the child who was
LATON
feeling ill made himself ^ sick eating too many
blueberries.

31. The owner of the boutique went to the optician next door to
TELEVISION
her shop ^ whenever she needed a new pair of contact
lenses.

E32a. The landlord told the janitor that the fireman with the
RENT(R1)
gas-mask would protect him/himself ^ from getting hurt.

E32b. The landlord told the janitor that the fireman with the
HERD(U1)
gas-mask would protect him/himself ^ from getting hurt.

E32c. The landlord told the janitor that the fireman with the
CLEAN(R2)
gas-mask would protect him/himself ^ from getting hurt.

E32d. The landlord told the janitor that the fireman with the
SCORE(U2)
gas-mask would protect him/himself ^ from getting hurt.

E32e. The landlord told the janitor that the fireman with the
SMOKE(R3)
gas-mask would protect him/himself ^ from getting hurt.

E32f. The landlord told the janitor that the fireman with the
SHIFT(U3)
gas-mask would protect him/himself ^ from getting hurt.

BLIFT

33. Unable to stop, the novice skier ^ continued down the steep
slope onto the frozen surface of the lake.
34. The group met every Saturday morning at the community truck center to rehearse the play they were to put on in the spring.

E35a. The professor told the sculptor that the comedian would federal(u1) entertain himself/him \after dinner tonight.

E35b. The professor told the sculptor that the comedian would college(r1) entertain himself/him \after dinner tonight.

E35c. The professor told the sculptor that the comedian would basket(u2) entertain himself/him \after dinner tonight.

E35d. The professor told the sculptor that the comedian would statue(r2) entertain himself/him \after dinner tonight.

E35e. The professor told the sculptor that the comedian would gang(u3) entertain himself/him \after dinner tonight.

E35f. The professor told the sculptor that the comedian would joke(r3) entertain himself/him \after dinner tonight.

FACE

36. The famous painting was sold to the \flamboyant millionaire at the recent auction in Paris.

PE37. The director convinced the playwright that the star of the infrep show would not let himself \have a drink before the performance.

38. The girl scout troop at the new school sold more cookies juppen last year than any other \troop in the whole state.

BOTLET

39. The saleswoman was \pleased when the attractive customer with the new sports car invited her to dinner.

E40a. The queen told the singer that the seamstress with the base(u1) busy schedule would remind her/herself \of the job that needed to be done.

E40b. The queen told the singer that the seamstress with the king(r1) busy schedule would remind her/herself \of the job that needed to be done.
E40c. The queen told the singer that the seamstress with the
FLOW(U2)
busy schedule would remind her/herself ^ of the job that needed
to be done.

E40d. The queen told the singer that the seamstress with the
SONG(R2)
busy schedule would remind her/herself ^ of the job that needed
to be done.

E40e. The queen told the singer that the seamstress with the
SKETCH(U3)
busy schedule would remind her/herself ^ of the job that needed
to be done.

E40f. The queen told the singer that the seamstress with the
THREAD(R3)
busy schedule would remind her/herself ^ of the job that needed
to be done.

TREE

41. After spending several years on the case, ^ the detective
finally found the evidence he needed to arrest the
assassin.

42. The principal of the public high school was delighted to
WRABLE
learn that one of her favorite ^ students had won the
writing competition.

E43a. The chemist warned the baker that the dentist with
LAB(R1)
the new office would blame himself/him ^ for the high cost of
the tests.

E43b. The chemist warned the baker that the dentist with
POD(U1)
the new office would blame himself/him ^ for the high cost of
the tests.

E43c. The chemist warned the baker that the dentist with
CAKE(R2)
the new office would blame himself/him ^ for the high cost of
the tests.

E43d. The chemist warned the baker that the dentist with
BOLT(U2)
the new office would blame himself/him ^ for the high cost of
the tests.

E43e. The chemist warned the baker that the dentist with
TOOTH(R3)
the new office would blame himself/him ^ for the high cost of
the tests.
E43f. The chemist warned the baker that the dentist with
FLOOD(U3)
the new office would blame himself/him ^ for the high cost of
the tests.

FANTER

44. It was the construction worker with the tattoo on his ^ chest
who was found guilty of the burglary.

PE45. The bookkeeper told the receptionist that the secretary
TAZE
for the vice president had made a fool of herself ^ during
the office party.

STRANK

46. The audience became ^ angry when the musicians, who
rarely performed in public, left the stage without giving
an encore.

E47a. The electrician convinced the plumber that the architect
WIRING(R1)
who owned the small company should give him/himself ^
a raise in pay.

E47b. The electrician convinced the plumber that the architect
LINING(U1)
who owned the small company should give him/himself ^
a raise in pay.

E47c. The electrician convinced the plumber that the architect
PIPE(R2)
who owned the small company should give him/himself ^
a raise in pay.

E47d. The electrician convinced the plumber that the architect
SLIP(U2)
who owned the small company should give him/himself ^
a raise in pay.

E47e. The electrician convinced the plumber that the architect
BUILDING(R3)
who owned the small company should give him/himself ^
a raise in pay.

E47f. The electrician convinced the plumber that the architect
TRAINING(U3)
who owned the small company should give him/himself ^
a raise in pay.

PE48. The tourist complained to the desk clerk that the chamber
CRIND
maid with black hair had not left him ^ a new set of towels
that morning.
49. The torrential rain storm caused the dam to break, flooding the nearby farm community.

BILTIN

50. An engineer was called in to inspect the building after renovations had been completed.

PE51. The technician informed the programmer that the student working in the lab would teach himself how to run the equipment for the experiment.

E52a. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

E52b. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

E52c. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

E52d. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

E52e. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

E52f. The burglar told the hunter that the minister would probably not protect himself/him under the circumstances.

GENTLE

53. It was only after the elderly couple had signed the contract that they were informed of the poor quality of the carpenter's work.

54. After spending ten years on the team, the star player retired his uniform to the hall-of-fame.

PE55. The grandmother promised the flower girl that the designer who had been hired would make her a beautiful dress for the upcoming wedding.

E56a. The girl told the ballerina that the heiress who was planning the luncheon would introduce her/herself to the famous diplomat.
E56b. The girl told the ballerina that the heiress who was BOY(U1)
planning the luncheon would introduce her/herself ^ to the famous diplomat.

E56c. The girl told the ballerina that the heiress who was BUILD(U2)
planning the luncheon would introduce her/herself ^ to the famous diplomat.

E56d. The girl told the ballerina that the heiress who was DANCE(R2)
planning the luncheon would introduce her/herself ^ to the famous diplomat.

E56e. The girl told the ballerina that the heiress who was CAMP(U3)
planning the luncheon would introduce her/herself ^ to the famous diplomat.

E56f. The girl told the ballerina that the heiress who was RICH(R3)
planning the luncheon would introduce her/herself ^ to the famous diplomat.

57. The ambulance was called by the frantic ^ mother whose son had just been attacked by a rabid dog.

E58a. The nephew warned the banker that the violinist who'd NIECE(R1)
gotten the tickets would be angry with himself/him ^ for forgetting about the show.

E58b. The nephew warned the banker that the violinist who'd CHOIR(U1)
gotten the tickets would be angry with himself/him ^ for forgetting about the show.

E58c. The nephew warned the banker that the violinist who'd MONEY(R2)
gotten the tickets would be angry with himself/him ^ for forgetting about the show.

E58d. The nephew warned the banker that the violinist who'd LOCAL(U2)
gotten the tickets would be angry with himself/him ^ for forgetting about the show.

E58e. The nephew warned the banker that the violinist who'd STRINGS(R3)
gotten the tickets would be angry with himself/him ^ for forgetting about the show.
E58f. The nephew warned the banker that the violinist who'd
gotten the tickets would be angry with himself/him
for forgetting about the show.

59. After receiving a degree in education, the young man taught
English for two years at a language institute in Tokyo.

PE60. The producer convinced the understudy that the theater
critic coming to that night's performance would speak
well of him in his review of the production.

61. At the reception following the lecture, the president of
the small college introduced the famous scholar to the head of the Physics department.

E62a. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

E62b. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

E62c. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

E62d. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

E62e. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

E62f. The gardener told the chauffeur that the attorney who'd won
the money might treat him/himself to an expensive dinner in a nice restaurant.

63. The nanny brought along a box full of toys and games in
case the children got bored at the family reunion.
E64a. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

E64b. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

E64c. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

E64d. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

E64e. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

E64f. The baroness told the nurse that the bride who was talking to the child would introduce herself/her to the band leader.

CHOZER

65. The tennis champion lost her chance at winning the cup due to a broken wrist.

DROCE

66. Several days after his car had been stolen, the young man received a phone call from his insurance company informing him that he needed to turn in a police report.

E67a The swimmer told the skater that the writer who had just arrived would get him/himself some lunch after the event.

E67b. The swimmer told the skater that the writer who had just arrived would get him/himself some lunch after the event.

E67c. The swimmer told the skater that the writer who had just arrived would get him/himself some lunch after the event.

E67d. The swimmer told the skater that the writer who had just arrived would get him/himself some lunch after the event.

E67e. The swimmer told the skater that the writer who had just arrived would get him/himself some lunch after the event.
E67f. The swimmer told the skater that the writer who had just
arrived would get him/himself some lunch after the event.

VELEPE

68. While they were at the playground, the children spent most
of their time on the merry-go-round.

E69a. The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

E69b. The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

E69c. The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

E69d The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

E69e. The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

E69f. The prince told the actor that the tailor from Singapore
would buy himself/him twenty yards of fine silk.

PE70. The client complained to the manager that the security
guard in the blue uniform had not allowed him into the
building earlier that day.

AMBEC

71. It was the young reporter who had investigated the
politician's illegal activities and broadcast the story
to the public.

CURTAIN

72. The forest ranger kept a close eye on the group of campers
to make sure they were following park regulations.

SEFFINION

73. Just after their first child was born, the couple moved to a new home across town.

E74a. The sailor told the lieutenant that the thief with the dark
clothes would supply him/himself with the stolen
equipment.
E74b. The sailor told the lieutenant that the thief with the dark NECK(U1) clothes would supply him/himself with the stolen equipment.

E74c. The sailor told the lieutenant that the thief with the dark WAR(R2) clothes would supply him/himself with the stolen equipment.

E74d. The sailor told the lieutenant that the thief with the dark END(U2) clothes would supply him/himself with the stolen equipment.

E74e. The sailor told the lieutenant that the thief with the dark ROB(R3) clothes would supply him/himself with the stolen equipment.

E74f. The sailor told the lieutenant that the thief with the dark LID(U3) clothes would supply him/himself with the stolen equipment.

75. Last year's best-selling novel was about the poor and RASTY homeless in America's largest cities.

PE76. The girl scout told the camper that her grandfather, who BROSET had just retired, had gotten himself a new canoe that afternoon.

SWOND

77. The high school student spent two hours every week tutoring a younger child in basic arithmetic.

WAPPLE

78. After the new cold medicine arrived in the drug store, the pharmacist was overwhelmed with customers.

E79a. The cowboy told the farmer that the sheriff of the small town GREEN(U1) would be proud of himself/him for saving the child's life.

E79b. The cowboy told the farmer that the sheriff of the small town HORSE(R1) would be proud of himself/him for saving the child's life.

E79c. The cowboy told the farmer that the sheriff of the small town PLASTER(U2) would be proud of himself/him for saving the child's life.
E79d. The cowboy told the farmer that the sheriff of the small town TRACTOR(R2) would be proud of himself/him for saving the child's life.

E79e. The cowboy told the farmer that the sheriff of the small town CEREAL(U3) would be proud of himself/him for saving the child's life.

E79f. The cowboy told the farmer that the sheriff of the small town DEPUTY(R3) would be proud of himself/him for saving the child's life.

TIRES

80. It was the caterer who found the newlywed's lost wedding ring in the punch bowl after the reception.

81. Eager to get a tan during his vacation, the college student LAQUOT spent too many hours on the beach and ended up badly burned.

E82a. The boy told the butler that the judge would be upset LAND(U1) with him/himself when the news became known.

E82b. The boy told the butler that the judge would be upset GIRL(R1) with him/himself when the news became known.

E82c. The boy told the butler that the judge would be upset HORN(U2) with him/himself when the news became known.

E82d. The boy told the butler that the judge would be upset MAID(R2) with him/himself when the news became known.

E82e. The boy told the butler that the judge would be upset BABY(U3) with him/himself when the news became known.

E82f. The boy told the butler that the judge would be upset JURY(R3) with him/himself when the news became known.

CRUSH

83. The supervisor of the advertising division upset the manager when he hired the president's son as his assistant.

84. The head flight attendant paid special attention to the LAIL passenger travelling with the newborn baby.
MONKEY

85. It took the jury only twenty minutes to reach a verdict.

E86a. The accountant told the detective that the duke from

   TAX(R1)

   the South of England would protect himself/him if there
   were an investigation.

E86b. The accountant told the detective that the duke from

   TOP(U1)

   the South of England would protect himself/him if there
   were an investigation.

E86c. The accountant told the detective that the duke from

   MURDER(R2)

   the South of England would protect himself/him if there
   were an investigation.

E86d. The accountant told the detective that the duke from

   JUNIOR(U2)

   the South of England would protect himself/him if there
   were an investigation.

E86e. The accountant told the detective that the duke from

   KING(R3)

   the South of England would protect himself/him if there
   were an investigation.

E86f. The accountant told the detective that the duke from

   BASE(U3)

   the South of England would protect himself/him if there
   were an investigation.
APPENDIX C.

STIMULUS MATERIALS FOR EXPERIMENT 2.3 (EXPERIMENTAL ITEMS ONLY)

E2a. The ballerina told the skier that the doctor for the team DANCE(R1) would probably blame him/her ^ for the recent injury.

E2b. The ballerina told the skier that the doctor for the team BUILD(U1) would probably blame him/her ^ for the recent injury.

E2c. The ballerina told the skier that the doctor for the team SLOPE(R2) would probably blame him/her ^ for the recent injury.

E2d. The ballerina told the skier that the doctor for the team TOAST(U2) would probably blame him/her ^ for the recent injury.

E5a. The photographer told the stewardess that the policeman MUSEUM(U1) in the blue uniform would protect her/him ^ if it became necessary.

E5b. The photographer told the stewardess that the policeman CAMERA(R1) in the blue uniform would protect her/him ^ if it became necessary.

E5c. The photographer told the stewardess that the policeman SCENE(U2) in the blue uniform would protect her/him ^ if it became necessary.

E5d. The photographer told the stewardess that the policeman PLANE(R2) in the blue uniform would protect her/him ^ if it became necessary.

E9a. The governess told the baker that the golfer with the new CLEAR(U1) car would teach him/her ^ how to drive this weekend.

E9b. The governess told the baker that the golfer with the new CHILD(R1) car would teach him/her ^ how to drive this weekend.

E9c. The governess told the baker that the golfer with the new BOLT(U2) car would teach him/her ^ how to drive this weekend.
E9d. The governess told the baker that the golfer with the new cake would teach him/her how to drive this weekend.

E14a. The artist told the heiress that the senator from paint California would buy her/him the tickets to the performance

E14b. The artist told the heiress that the senator from bread California would buy her/him the tickets to the performance

E14c. The artist told the heiress that the senator from rich California would buy her/him the tickets to the performance

E14d. The artist told the heiress that the senator from camp California would buy her/him the tickets to the performance

E17a. The cleaning lady told the accountant that the reporter mop from the city might introduce him/her to the French Count.

E17b. The cleaning lady told the accountant that the reporter paw from the city might introduce him/her to the French Count.

E17c. The cleaning lady told the accountant that the reporter tax from the city might introduce him/her to the French Count.

E17d. The cleaning lady told the accountant that the reporter top from the city might introduce him/her to the French Count.

E20a. The archer told the girl that the pilot with the blond decay hair might introduce her/him to the famous movie star.

E20b. The archer told the girl that the pilot with the blond arrow hair might introduce her/him to the famous movie star.

E20c. The archer told the girl that the pilot with the blond job hair might introduce her/him to the famous movie star.

E20d. The archer told the girl that the pilot with the blond boy hair might introduce her/him to the famous movie star.
E25a. The duchess told the priest that the general who was still HINT(U1) overseas would not forgive him/her ^ for last week's disaster.

E25b. The duchess told the priest that the general who was still DUKE(R1) overseas would not forgive him/her ^ for last week's disaster.

E25c. The duchess told the priest that the general who was still COURSE(U2) overseas would not forgive him/her ^ for last week's disaster.

E25d. The duchess told the priest that the general who was still CHURCH(R2) overseas would not forgive him/her ^ for last week's disaster.

E27a. The nephew told the baroness that the physician from out NIECE(R1) of town would take care of her/him ^ during the holidays.

E27b. The nephew told the baroness that the physician from out CHOIR(U2) of town would take care of her/him ^ during the holidays.

E27c. The nephew told the baroness that the physician from out BARON(R2) of town would take care of her/him ^ during the holidays.

E27d. The nephew told the baroness that the physician from out PLAZA(U2) of town would take care of her/him ^ during the holidays.

E32a. The landlord told the nun that the fireman with the gas-mask RENT(R1) would protect him/her ^ from getting hurt.

E32b. The landlord told the nun that the fireman with the gas-mask HERD(U1) would protect him/her ^ from getting hurt.

E32c. The landlord told the nun that the fireman with the gas-mask PRAY(R2) would protect him/her ^ from getting hurt.

E32d. The landlord told the nun that the fireman with the gas-mask BARK(U2) would protect him/her ^ from getting hurt.

E35a. The king told the actress that the comedian would THRIFT(U1) entertain her/him ^ after dinner tonight.
E35b. The king told the actress that the comedian would  
    THRONE(R1)  
    entertain her/him ^ after dinner tonight.

E35c. The king told the actress that the comedian would  
    SPACE(U1)  
    entertain her/him ^ after dinner tonight.

E35d. The king told the actress that the comedian would  
    STAGE(R1)  
    entertain her/him ^ after dinner tonight.

E40a. The policewoman told the journalist that the professor with  
    PUNCH(U1)  
    the busy schedule would remind him/her ^ of the job that needed  
    to be done.

E40b. The policewoman told the journalist that the professor with  
    BADGE(R1)  
    the busy schedule would remind him/her ^ of the job that needed  
    to be done.

E40c. The policewoman told the journalist that the professor with  
    MASS(U1)  
    the busy schedule would remind him/her ^ of the job that needed  
    to be done.

E40d. The policewoman told the journalist that the professor with  
    NEWS(R1)  
    the busy schedule would remind him/her ^ of the job that needed  
    to be done.

E43a. The chemist warned the saleslady that the dentist with  
    LAB(R1)  
    the new office would blame her/him ^ for the high cost of the  
    tests.

E43b. The chemist warned the saleslady that the dentist with  
    POD(U1)  
    the new office would blame her/him ^ for the high cost of the  
    tests.

E43c. The chemist warned the saleslady that the dentist with  
    SELL(R2)  
    the new office would blame her/him ^ for the high cost of the  
    tests.

E43d. The chemist warned the saleslady that the dentist with  
    PATH(U2)  
    the new office would blame her/him ^ for the high cost of the  
    tests.
E47a. The electrician convinced the maid that the architect who owned the small company should give him/her a raise in pay.

E47b. The electrician convinced the maid that the architect who owned the small company should give him/her a raise in pay.

E47c. The electrician convinced the maid that the architect who owned the small company should give him/her a raise in pay.

E47d. The electrician convinced the maid that the architect who owned the small company should give him/her a raise in pay.

E52a. The waitress told the hunter that the minister would probably not protect her/him under the circumstances.

E52b. The waitress told the hunter that the minister would probably not protect her/him under the circumstances.

E52c. The waitress told the hunter that the minister would probably not protect her/him under the circumstances.

E52d. The waitress told the hunter that the minister would probably not protect her/him under the circumstances.

E56a. The model told the lieutenant that the sculptor who was planning the luncheon would introduce him/her to the famous diplomat.

E56b. The model told the lieutenant that the sculptor who was planning the luncheon would introduce him/her to the famous diplomat.

E56c. The model told the lieutenant that the sculptor who was planning the luncheon would introduce him/her to the famous diplomat.
E56d. The model told the lieutenant that the sculptor who was planning the luncheon would introduce him/her ^ to the famous diplomat.

E58a. The queen warned the banker that the violinist who’d gotten the tickets would be angry with her/him ^ for forgetting about the show.

E58b. The queen warned the banker that the violinist who’d gotten the tickets would be angry with her/him ^ for forgetting about the show.

E58c. The queen warned the banker that the violinist who’d gotten the tickets would be angry with her/him ^ for forgetting about the show.

E58d. The queen warned the banker that the violinist who’d gotten the tickets would be angry with her/him ^ for forgetting about the show.

E62a. The gardener told the seamstress that the attorney who’d won the money might treat him/her ^ to an expensive dinner in a nice restaurant.

E62b. The gardener told the seamstress that the attorney who’d won the money might treat him/her ^ to an expensive dinner in a nice restaurant.

E62c. The gardener told the seamstress that the attorney who’d won the money might treat him/her ^ to an expensive dinner in a nice restaurant.

E62d. The gardener told the seamstress that the attorney who’d won the money might treat him/her ^ to an expensive dinner in a nice restaurant.

E64a. The princess told the butler that the captain from the ship would introduce her/him ^ to the band leader.

E64b. The princess told the butler that the captain from the ship would introduce her/him ^ to the band leader.
E64c. The princess told the butler that the captain from the ship MAID(R2) would introduce her/him ^ to the band leader.

E64d. The princess told the butler that the captain from the ship HORN(U2) would introduce her/him ^ to the band leader.

E67a. The speed skater told the nurse that the writer who had just CUP(U1) arrived would get him/her ^ some lunch after the event.

E67b. The speed skater told the nurse that the writer who had just ICE(R1) arrived would get him/her ^ some lunch after the event.

E67c. The speed skater told the nurse that the writer who had just ATTITUDE(U2) arrived would get him/her ^ some lunch after the event.

E67d. The speed skater told the nurse that the writer who had just HOSPITAL(R2) arrived would get him/her ^ some lunch after the event.

E69a. The bride told the actor that the tailor from Singapore GROOM(R1) would buy her/him ^ twenty yards of fine silk.

E69b. The bride told the actor that the tailor from Singapore FLASK(U1) would buy her/him ^ twenty yards of fine silk.

E69c. The bride told the actor that the tailor from Singapore MOVIE(R2) would buy her/him ^ twenty yards of fine silk.

E69d. The bride told the actor that the tailor from Singapore PANEL(U2) would buy her/him ^ twenty yards of fine silk.

E74a. The sailor told the singer that the thief with the dark SHIP(R1) clothes would supply him/her ^ with the stolen equipment.

E74b. The sailor told the singer that the thief with the dark NECK(U1) clothes would supply him/her ^ with the stolen equipment.

E74c. The sailor told the singer that the thief with the dark SONG(R2) clothes would supply him/her ^ with the stolen equipment.
E74d. The sailor told the singer that the thief with the dark clothes would supply him/her with the stolen equipment.

E79a. The midwife told the farmer that the sheriff of the small town would be proud of her/him for saving the child's life.

E79b. The midwife told the farmer that the sheriff of the small town would be proud of her/him for saving the child's life.

E79c. The midwife told the farmer that the sheriff of the small town would be proud of her/him for saving the child's life.

E79d. The midwife told the farmer that the sheriff of the small town would be proud of her/him for saving the child's life.

E82a. The boy told the teller that the judge would be upset with him/her when the news became known.

E82b. The boy told the teller that the judge would be upset with him/her when the news became known.

E82c. The boy told the teller that the judge would be upset with him/her when the news became known.

E82d. The boy told the teller that the judge would be upset with him/her when the news became known.

E86a. The hostess told the detective that the duke from the South of England would protect her/him if there were an investigation.

E86b. The hostess told the detective that the duke from the South of England would protect her/him if there were an investigation.
E86c. The hostess told the detective that the duke from MURDER(R2) the South of England would protect her/him ^ if there were an investigation.

E86d. The hostess told the detective that the duke from JUNIOR(U2) the South of England would protect her/him ^ if there were an investigation.