Frazier, L., & Clifton, C., Jr. (2002). Processing 'd-linked' phrases. Journal of Psycholinguistic Research., 31, 633-660.

Processing 'd-linked' phrases

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Abstract

Linguists draw a distinction between two types of interrogatives: d-linked (discourse linked) phrases such as which man, which implies the existence of a set of contextually-determined entities (men) from which the speaker is asking for a choice, and non-d-linked interrogatives such as who, which carry no such implication. Two questionnaires and an on-line reading study showed that readers prefer a d-linked phrase more than a non-d-linked phrase as the antecedent for a pronoun, suggesting that d-linked phrases are immediately instantiated in a discourse representation which is checked during the process of pronoun interpretation. Comparable difficulty is not observed for non-d-linked interrogatives. A questionnaire and an on-line listening study also showed that readers and listeners were more willing to accept a grammatical "island violation" containing a pronoun when the pronoun's antecedent was a d-linked interrogative than when the antecedent was non-d-linked, suggesting that they check a discourse representation for the pronoun antecedent. All results suggest that d-linked phrases are immediately interpreted in a discourse representation, not just in a syntactic representation.

Keywords: discourse linking, anaphora, syntax-semantics interface, semantic interpretation

Linguists draw a distinction between two types of wh-phrases. Interrogative phrases like which man imply the existence of a context set of familiar entities of the type denoted by the nominal, e.g., a set of already familiar men. These have been called "d-linked" (discourse-linked) (see Pesetsky, 1987, and Enç, 1991). They contrast with interrogative pronouns like who which carry no necessary implication about familiar discourse entities. Pesetsky (1987) presents the examples in (1) in support of the distinction, noting that in (1b) "it is natural, almost obligatory, to assume that the question is asking for a choice among the men who entered the room." In (1c), "considerations of textual correctness make this assumption possible but much less natural" (p. 120).

(1) a. Some men entered the room. Mary talked to them.

b. Some men entered the room. Which (ones) did Mary talk to?

c. Some men entered the room. Who did Mary talk to?

The distinction between the discourse-linked which N phrase and the non-discourse-linked who is a semantic distinction, or at least a discourse-appropriateness distinction. It has syntactic consequences as well, at least consequences for the LF ("logical form") level of representation (cf. Pesetsky, 1987). For instance, as Pesetsky notes, non-d-linked interrogatives obey "Superiority," which requires the higher of two phrases (who as opposed to what in (2)) to move, as indicated in (2).

(2) a. Mary asked [who$_i$[e$_i$ read what]]?

b. *Mary asked [what$_i$[who read e$_i$]]?

Surprisingly, d-linked phrases can violate Superiority, as illustrated in (3), both of which are

acceptable to many (but not all) English speakers.

(3) a. Mary asked which man$_i$ [e$_i$ read which book]?

b. Mary asked which book$_i$ [which man read e$_i$]?

The distinction between d-linked and non-d-linked-phrases has processing consequences. Radó (1998) reported that subjects in a sentence-completion task were more likely to continue fragments like "What/Which phrase did the lecturer say ____" with the wh-phrase associated with the subject position of the complement of say for which N than for what. Since the subject position is the default topic position, and since topics are discourse entities par excellence, this suggests that which N is particularly likely to be taken to correspond to a discourse entity. Radó also reported a self-paced reading task that supported a similar conclusion. Sentences were read relatively quickly when they forced which N to be the subject of a complement sentence (as in (4a)) or what to be the object of the matrix sentence (4b) than when the other assignments were forced (4c, d).

(4) a. What phrase did the lecturer say made the local authorities very concerned?

b. What did the lecturer say when the class was almost over?

c. What phrase did the lecturer say when the class was almost over?

d. What did the lecturer say made the local authorities very concerned?

In her research, Radó emphasizes the importance of associating which N with subject position, and argues that the link between subject, topic, and given (vs. new) status means that givenness rather than d-linking per se is crucial to the effects she observes.

De Vincenzi (1991) has reported a superficially contrasting effect in Italian. She found

that sentences like (5) were more likely to be given an interpretation in which the (non-d-linked) interrogative chi is extracted from subject position than from object position. This difference disappeared in sentences with d-linked interrogatives, such as quale ragazza (6). Further, disambiguated subject-gap counterparts of (5 and 6) were read faster than object-gap versions only for the non-d-linked chi.

(5) Chi ha chimato Giovanni?

Who has called Giovanni? (meaning "Who has called Giovanni" [preferred] or "Who has Giovanni called?")

(6) Quale ragazza ha chiamato Giovanni?

Which girl has called Giovanni? (meaning "Which girl has called Giovanni" or "Which girl has Giovanni called?")

On the surface, this difference appears to be the opposite of the subject-extraction preference Radó reported for English. However, Italian syntax is not the same as English. As De Vincenzi discusses, in sentences like (5) chi must enter into a syntactic (movement) chain, while quale N in (6) need not. Instead, quale N can be interpreted as designating a discourse entity that can be co-indexed with the empty position in the question. Following De Vincenzi's "minimal chain p0rinciple," chi must be assigned to a gap position as soon as possible, which will be the subject position. Quale N does not have to obey this principle, allowing it to be coindexed with the object position. Under this analysis, the effect that d-linking will be observed to have on sentence processing can depend on subtle interactions between its syntax and its semantics.

Shapiro, Oster, Garcia, Massey and Thompson (1999) conducted a cross-modal priming

study to test the hypothesis that d-linked phrases require a link to discourse, which adds a processing burden, and thus delays activation of a d-linked (which) phrase relative to an indefinite interrogative such as who or what. For who or what, priming was observed at the interrogative and again at the position of the trace. For which phrases, suggestions of reactivation of the interrogative phrase occurred at the trace position, but priming was not clear or significant until the post-trace position.

Frazier, Plunkett and Clifton (1996) proposed that a reader quickly postulates the existence of a discourse referent for d-linked interrogative phrase. Frazier et al. contrasted the processing of non-d-linked interrogative pronouns and d-linked interrogative phrases in sentences like those in (7), where the nature of the embedded verb was also manipulated.

(7) a. Which boy did Tom say that every girl saw?

b. Who did Tom say that every girl saw?

c. Which boy did Tom say that every girl married?

d. Who did Tom say that every girl married?

In (7a,b) a neutral verb see occurs; it carries no constraint on the natural pairing of girls and boys. In (7c,d), see is replaced with a biased verb, marry; the biased verb describes a situation with a common or natural one-to-one pairing of girls and boys. If it is true that readers postulate a discourse referent for which boy by the left boundary of the embedded clause in (7a,c), then difficulty should occur in the processing of (7c). In (7c), the assumption of a singular discourse entity corresponding to which boy must be retracted in order to multiply instantiate boys and satisfy the bias of marry. By contrast, who should not exhibit any difficulty in (7d), relative

to (7b), since who is not d-linked and, hence, no discourse entity corresponding to who should be postulated at the clause boundary. The results of a self-paced reading study provided some support for these predictions: (7c) was more difficult to process than the other sentences in (7).

The experiments reported here extend these studies of the syntax-semantics interface. The initial experiments test for the effect that d-linked vs. non-d-linked interrogatives may have on availability of a discourse entity by examining the processing of pronouns. They assume that a pronoun's most favored antecedent is an entity in a discourse model, an assumption that stems from the position that pronouns and other "deep anaphors" are interpreted in terms of reference to entities in a discourse model (Sag & Hankamer, 1984). One simple piece of evidence favoring our assumption is the widely observed preference for pronouns to take topical antecedents (cf. Reinhart, 1982). Assuming that topic is defined in discourse terms, this implies that the processor consults the discourse representation in its search for the referent of a pronoun.

In addition, there is experimental evidence that indicates that a discourse entity is a possible, or even a preferred, antecedent for a pronoun. Although Garnham, Oakhill, Ehrlich and Carreiras (1995) demonstrated that gender-marked French and Spanish pronouns can find antecedents of the proper gender even when gender is marked only in the superficial linguistic form, they also reported that a semantic reflex of gender (sex of the referent) serves as a more stable, permanent, and accessible basis for selecting an antecedent or referent of a pronoun. Garnham et al. take this to suggest that pronouns may generally find their antecedents/referents in a discourse model, and that the discourse model may contain information about the grammatical gender of the terms that refer to its entities, eliminating any need to appeal to antecedents in a

superficial linguistic representation. Using a variety of techniques, others have argued for a similar conclusion in processing pronouns in Spanish (Carreiras and Gernsbacher, 1992) and Dutch (Frazier, Henstra and Flores d'Arcais, 1996).

Using quite different logic, Cloitre and Bever (1988) also presented evidence that pronouns typically find their antecedents or referents in a "conceptual" representation (presumably a representation of the discourse). Their subjects were timed while recognizing the adjective (gangly or smart, for different subjects) that modified a noun that served as the antecedent of a pronoun (him in (8a)) or a definite NP (the busboy in (8b)). They found that, when the prime was a pronoun as in (8a), "concrete" adjectives (e.g., gangly) showed stronger priming effects (faster recognition compared to a control that contained no anaphor) than "abstract" adjectives (e.g., smart). The priming advantage for concrete adjectives was less when the priming anaphor was a definite noun phrase, as in (8b).

(8) The gangly/smart busboy spilled the soup on the famous actress.

(a) A waiter ran to help him. GANGLY/SMART

(b) A waiter ran to help the busboy. GANGLY/SMART

Assuming that concrete information is more readily available in a conceptual representation than abstract information is, these results suggest that the processor checks the conceptual or discourse representation when it searches for an antecedent for a pronoun but is more likely to check the superficial linguistic form when finding an antecedent for a definite NP.

In the present study, we wish to examine the hypothesis that the processor postulates a discourse entity corresponding to the referent of a d-linked phrase at least by the end of its clause

(e.g., before entering a subordinate clause), whereas no such postulation is made when processing interrogative pronouns. If the hypothesis is correct, then a d-linked interrogative phrase should be more readily available as an antecedent/referent for a personal pronoun than an indefinite interrogative is. Experiment 1 tests this prediction in a questionnaire study.[1]

Experiment 1

Method

Materials. Twelve sentences containing embedded questions (illustrated in 9) and 12 matrix questions (in 10) were constructed. The materials used in Experiment 1 appear in Appendix A. There was a non-d-linked (who) and a d-linked (which N) version of each (a and b, respectively).

(9) a. Rick knew who Janice sang a song to before he went to sleep.

b. Rick knew which brother Janice sang a song to before he went to sleep.

(10) a. Who did Bradley send a rifle to when he was threatened?

b. Which guy did Bradley send a rifle to when he was threatened?

Both embedded question and matrix question sentences were used to explore the generality of the effect we were searching for, and to minimize the number of sentences that were superficially alike.

Each of these sentences contained a feminine or a masculine personal pronoun with two potential antecedents: the wh-element (who or which N) or a noun phrase of the appropriate number and gender to serve as antecedent for the personal pronoun (e.g, Rick or Bradley). Each sentence was combined with a two-choice answer (e. g., "Who went to sleep? Rick ___ The

person Janice sang a song to ___") for incorporation in a questionnaire. If the d-linked phrase leads the processor to postulate a discourse entity but the non-d-linked interrogative pronoun does not, then the wh-antecedent should be chosen as antecedent of the personal pronoun more often when the pronoun follows the d-linked phrase in (9b, 10b) than when it follows the non-d-linked phrase (9a, 10a).

These 24 items were divided into two counterbalanced questionnaire forms, such that the d-linked versions of half the items appeared in one form together with the non-d-linked versions of the remaining items. The second form contained the other half of the items. The experimental items were combined with 32 noun phrases with modifying adjectives, each in one of eight different syntactic configurations, to be rated for plausibility, and 16 "sluicing" sentences (e.g., "Some tourist suspected that the hotelkeeper was hiding someone -- guess who.") Subjects were to choose between two possible referents of the final who in these sentences.

Subjects and procedure. Sixty University of Massachusetts undergraduates were given a version of the questionnaire, with instructions to give their initial interpretation of each sentence (or for the fillers, to rate its plausibility). They received course credit for participating in the study.

Results

Table 1 presents the mean proportion of sentences for which the wh-element was chosen as antecedent for the personal pronoun, as indicated by the answers to the question following each sentence. The wh-element was chosen as antecedent for the pronoun more often in d-linked questions than in non-d-linked who-questions ($F1(1,59) = 29.64$, $p < .001$; $F2(1,23) = 9.19$, $p <$

.01). The same pattern held true for both embedded questions and matrix questions, considered separately.

--- Table 1 about here —

Discussion

The data clearly support the prediction that a presumably d-linked interrogative phrase (which-N) is more available as an antecedent for a pronoun than the non-d-linked who. We propose that this is because the d-linked phrase requires the postulation of a discourse entity, while who does not. Since pronouns seem to prefer antecedents in a discourse representation, this makes which-N relatively more available.

However, the explicit noun in a which-N phrase introduces other potentially-relevant information over and above its d-linked nature. In the first place, it often introduces determinate gender. Which boy is unambiguously masculine, and thereby an acceptable antecedent for the pronoun he. Who is also an acceptable antecedent for the pronoun he, but is not explicitly masculine. Further, a which-N phrase can be unambiguously marked for number, while in English, who may be grammatically singular without making a commitment to a notionally singular referent. One can view these sources of information either as confounds or as possible bases for d-linking. It may be that a more fully specified phrase is more likely to be used as the source of a discourse entity, and the gender and number specifications on which-N make it a good candidate for such a source.

It is nonetheless possible to ask whether the apparent d-linking effect will still appear when gender-neutral nouns are used.[2] If the effect still appears under these circumstances, it

cannot be attributed entirely to gender-specificity. Experiment 2 investigated this possibility using gender-neutral phrases such as which person.

Experiment 2

Method

Materials. Twelve sentences containing embedded questions, and twelve matrix questions, were constructed. Examples appear in (11) and (12).

(11) a. Rick knew who Janice sang a song to before he went to sleep.

b. Rick knew which visitor Janice sang a song to before he went to sleep.

(12) a. Who did Brian send a rifle to when he was threatened?

b. Which friend did Brian send a rifle to when he was threatened?

The materials were similar to the Experiment 1 items, but consistently contained gender-neutral nouns in the which-N phrase (e.g, visitor, student, neighbor, child, colleague). All materials appear in Appendix B.

Two forms of a questionnaire were constructed containing only these sentences. The who version of a sentence appeared in one form, and the which-N version in the other form. Each form contained equal numbers of who and which-N sentences. Two different random orders of the sentences were used for each form. Each sentence was followed by two alternative antecedents for the pronoun contained in the sentence, as in Experiment 1. Half the items had the wh-phrase antecedent on the left, and half had the matrix subject (for embedded questions) or the embedded subject (for matrix questions) antecedent on the left.

Subjects and procedures. Forty-eight University of Massachusetts undergraduates

completed the questionnaires. Each was tested individually after completing an unrelated 25-minute experiment, and each received course credit for participating.

Results

The proportions of choice of the wh-phrase as antecedent of the pronoun appear in Table 1. As in Experiment 1, which-N was chosen as antecedent more often than who, 45 vs. 38% of the time. This difference does appear to be substantially smaller than the 56 vs 41% effect observed in Experiment 1, but still is trustworthy. An analysis of variance indicated that the effect of which-N vs. who was conventionally significant by subjects ($F1(1,47) = 5.49$, $p < .03$, and marginally significant by items ($F1(1,22) = 3.76$, $p = .065$). Performing an arc-sin transformation on the proportions (to better satisfy the assumptions of the F-test) and pooling over indirect and direct questions (which did not differ) resulted in conventional significance by items as well ($F1(1,23) = 4.32$, $p < .05$).

Further, an additional 48 subjects were tested on the same items, but this time intermixed with three other types of items (48 such items in all). Each of these other items required a choice between two interpretations, just as the wh-phrase items under discussion here. The procedures used were the same as in Experiment 2, except that the wh-phrase antecedent alternative always appeared as the second choice. The results were very similar to those observed in Experiment 2, 42% choice of the which-N antecedent as compared to 35% choice of the who antecedent. This difference was again significant by subjects ($F1(1,47) = 4.69$, $p < .04$), but not by items ($F1(1,22) = 2.86$, $p = .10$; reduced to $p = .07$ by the arc sin transformation). While the effect is clearly small, near the resolving power of the experimental procedures, it is almost certainly real. Under

the null hypothesis, the joint probability of obtaining the significance levels in the two replications is far less than .01.

Experiment 3

Experiments 1 and 2 tested the discourse instantiation hypothesis in an off-line questionnaire study. Experiment 3 provides an on-line test to ensure that the hypothesized postulation of a discourse entity corresponding to a d-linked phrase occurs during sentence comprehension and not as part of an after-the-sentence reasoning process necessitated by the task of choosing an antecedent for the pronoun. A self-paced reading technique was used to measure the speed of reading sentences that were similar to the items used in Experiment 1.

Method

Materials. The materials of Experiment 1 were adapted by changing the gender of NPs and/or the pronoun so that only the wh-phrase was appropriate to serve as antecedent of the personal pronoun, as illustrated in (13) and (14). Each item had two forms, one with a masculine pronoun and antecedent, and the other with a feminine pronoun and antecedent. Various changes were made in the materials from Experiment 1 to permit both masculine and feminine versions of each item (e.g., changing names to equate male and female name length, changing predicate to maintain plausibility of both genders). As in Experiment 1, half the items were direct questions and half contained embedded (indirect) questions. Both the masculine pronoun and the feminine pronoun version of each of two items are illustrated in (13) and (14), where the ^ indicates the division into the sentence regions that were presented in the experiment.

(13) a. Rick knew who Josh sang a song to ^ before she went to sleep.

a'. Rita knew who Joan sang a song to ^ before he went to sleep.

b. Rick knew which sister Josh sang a song to ^ before she went to sleep.

b'. Rita knew which brother Joan sang a song to ^ before he went to sleep.

(14) a. Who did Becky send a rifle to ^ when he was threatened?

a'. Who did Brian send a rifle to ^ when she was threatened?

b. Which guy did Becky send a rifle to ^ when he was threatened?

b'. Which woman did Brian send a rifle to ^ when she was threatened?

Twenty-four experimental items were included in the list of sentences each subject read. Twelve items were direct questions, and 12 were embedded questions. Half of the items appeared with a masculine pronoun, and half with a feminine pronoun. Orthogonally, half the items of each type contained who as the wh-phrase, and half contained which N. Four experimental lists were constructed, so that <u>who</u> vs. <u>which-N</u> and masculine vs. feminine pronoun were counterbalanced across lists, and so that each list contained six instances of the four possible types of items. All materials used in Experiment 3 appear in Appendix C.

These 24 experimental items were included in a list of 175 sentences total, representing a wide variety of syntactic constructions (and including several other experiments as well as filler items). Each experimental sentence was divided into two presentation regions, as indicated by the ^ in (13) and (14). Twelve of the 24 experimental items (6 embedded and 6 matrix questions) were followed by questions such as "What did John do? sang a song / went to sleep," as were 53 of the remaining sentences. A practice list of nine unrelated items, five with questions, was also

constructed.

Subjects and procedures. Forty-eight undergraduates at the University of Massachusetts were tested in individual 40-min sessions. Each subject received instructions and then was tested with the practice list. The subject first saw a series of underline marks on a computer monitor, each underline representing a character in the next sentence, while holding his or her hands on a response console that contained three microswitches, one under the left side of the monitor and two under the right side of the monitor (one for thumb, one for right forefinger). When the subject pulled the lever on which his or her right forefinger rested, the first presentation segment of the sentence appeared. The subject was to read this segment and then pull the lever to read the second segment, and then pull it again to indicate that he or she had finished reading. If a question was scheduled to appear after the sentence, the word QUESTION would appear for 500 ms. followed by the question and its two answers, one on the left side of the screen and one on the right. The subject was to pull the lever under the correct answer. If the wrong lever was pulled, the word ERROR would appear on the screen for 1000 ms. Otherwise, the underscore marks for the next sentence appeared. The time taken to read each segment of the sentence, and the question-answering accuracy and time, were recorded. A short break followed the practice list, and then the experimental list was presented. The 175 items were presented in individually-randomized order, following the procedures described above.

Results

Questions were answered correctly 82% of the time. Since we questioned only half the items, we cannot conditionalize our primary analysis of reading times upon question-answering

accuracy (however, see below for a conditionalized analysis of the items that did receive questions). We believe that the 82% accuracy means that our subjects were resolving the pronoun correctly most of the time, so that any effects of type of antecedent can be attributed to proper comprehension of the sentence.

The mean reading times for presentation segment 2 appear in Table 2. They are presented in ms/char, not because of the need to adjust for length differences among experimental conditions (which did not exist), but to achieve rough comparability among different sentences and thus reduce error variance compared to unadjusted times.

--- Table 2 about here ---

The mean ms/char reading times were analyzed in a three-way analysis of variance, with factors who vs. which-N, embedded vs. matrix question, and masculine vs. feminine pronoun. The second presentation segment was read faster when the antecedent of its pronoun was a d-linked which-N phrase in the first segment than when it was the non-d-linked word who (58.5 vs 62.9 ms/char; $F1(1, 47) = 12.37$, $p < .001$; $F2(1, 22) = 10.24$, $p < .01$.

As mentioned earlier, the reading times used in this analysis were not conditionalized upon question-answering accuracy, because only half the items were questioned. However, a subsidiary analysis of this half of the items, conditionalized upon a correct answer, provided supporting data. Mean reading time for the second segment of who sentences was 64.5 ms, while it was 58.0 ms for which-N sentences, very close to the overall values of 62.9 and 58.5 ms.

Returning to the main analysis, the three-way interaction among matrix vs. embedded X masculine vs. feminine X who vs which N was nearly significant ($F1(1,47) = 6.96$, $p < .02$;

F2(1,22) = 3.99, p < .06). As can be seen in Table 2, there was an advantage of which-N over who in each of the four possible contrasts, but the direct question-male and embedded question-feminine produced numerically the largest effects. Little can be made of this finding, since a replication (identical aside from the need to discard one sentence because of a typographical error, and the use of a different 94 filler items in the list of sentences a subject saw) produced a fully significant which-N advantage as seen in Experiment 2 (69.2 vs 66.1 ms/char for who and which N sentences respectively; F1(1,47) = 5.81, p < .02; F2(1,20) = 7.52, p < .02), but no sign of the three-way interaction. The only other nearly-significant effect in the primary experiment was the interaction of main vs. embedded question and masculine vs. feminine pronoun (F1(1,47) = 8.29, p < .01; F2(1,22) = 3.62, p = .07), but this interaction (which actually reflects the three-way interaction) also disappeared in the replication (to be replaced by a significant but otherwise-unobserved advantage of feminine over masculine pronouns).

Discussion

Could the results of Experiments 1-3 be attributed directly to a process whereby DPs that support the features of a pronoun are preferred antecedents and are processed more quickly than antecedents which are merely consistent with the features of the pronoun? At first blush, this "featural support hypothesis" looks like a sensible account of the results. But we think here is reason to be skeptical about it.

Consider Experiment 2 where gender is neutral. "Who" and "which visitor" are both grammatically singular (e.g. "Who is coming to the party?/*Who are coming to the party?). It is unclear why the d-linked phrase better supports the singular number features of "he" than "who"

does. Neither interrogative phrase contains an overt singular morpheme and both are grammatically singular. Nevertheless, the d-linked phrase was chosen as the antecedent of the pronoun more often than the non-d-linked phrase.

It may be possible to develop some version of a featural-support hypothesis that will account for the results of the above experiments. Such a hypothesis would need to attribute 'featural support' to something other than the grammatical features of an antecedent to account for Experiment 2. Presumably the relevant feature would index the semantic or discourse differences between who and which-N) and thus would be similar to the discourse instantiation hypothesis proposed here. Rather than pursue this issue further, we will test the discourse instantiation hypothesis in sentences which use pronouns in a very different way, generally considered ungrammatical, and obtained judgments of acceptability rather than measures of processing ease.

Experiment 4

Experiment 4 investigated the acceptability of sentences with a pronoun inside an island. In these sentences, such as (15), there was no empty category for the interrogative phrase to bind.

(15) a. (*)Which students did the teacher wonder if they had gone to the library?

b. (*)Who did the teacher wonder if they had gone to the library?

Assuming that resumptive pronouns are ungrammatical in English, both sentences forms (15a) and (15b) are ungrammatical: the interrogative does not bind a trace. However, we expected (15a) with a d-linked interrogative to be judged more acceptable than (15b). Readers should be more likely to take the discourse entity corresponding to the d-linked interrogative to be the

referent of the pronoun in (15a). Consequently they may arrive at an interpretation of (15a) which is perfectly sensible, if ungrammatical when treated as a single sentence. In (15b), there is less clearly a discourse entity corresponding to who. Thus, in (15b) we expected readers to be less likely to establish a relation between the interrogative and the pronoun (and perhaps less satisfied with the relation if they do establish it). Therefore (15b) should be degraded not only because the interrogative fails to bind a trace but also because no sensible interpretation reliably emerges.

Methods

Materials. Twenty four ungrammatical sentence pairs were constructed, with a d-linked (which N') and non-d-linked (who) form of each. As in (15), the sentences contained a pronoun in subject position of a wh-island. In half the sentences the interrogative constituent and pronoun were human; in half they were inanimate. For each type (human vs. inanimate), half were singular and half were plural. The interrogative phrase was the only phrase in the sentence with number compatible with the number of the pronoun.

The number of the interrogative phrase was manipulated in order to determine whether d-linked antecedents for pronouns are generally preferred to non-d-linked ones or whether this is true only or primarily for plural d-linked phrases. Given that non-d-linked phrases are not overtly marked for number (plural), and thus may tend to be interpreted as (default) singulars, it is possible that the d-linking preference might be restricted to plural d-linked phrases. The opposite possibility arises because singular but not plural pronouns are marked for gender. To the extent that the preference for a which-N antecedent for a pronoun is due to an explicit gender match between the (singular) pronoun and the antecedent, the preference should appear only for

singular d-linked phrases. All materials used in Experiments 4 and 5 appear in Appendix D.

Subjects and procedures. The experimental sentences were printed as two forms of a questionnaire. One form contained the d-linked (which N) versions of half the sentences and the non-d-linked (who) versions of the rest; the other form contained the other version of each sentence. A single random order was used, which does not compromise interpretation of the d-linking effect since both d-linked and non-d-linked forms appeared equally at each serial position. Beneath each sentence there appeared a scale form 1-7, as in (16).

(16) Which students did the teacher wonder if they had gone to the library.

1 2 3 4 5 6 7

acceptable unacceptable

Nineteen University of Massachusetts undergraduates were given Form 1 to complete, and 20 were given Form 2. The questionnaire contained written instructions asking the subject to circle a number on the scale from 1 to 7, where 1 means that a sentence sounds perfectly fine and 7 means a sentence is completely terrible. Each subject received several additional sentence-interpretation and sentence-rating questionnaires (not the same ones for all subjects). The entire set of questionnaires given to one subject took less than ½ hour to complete.

Results

Table 3 presents the mean sentence ratings (1 = good, 7 = terrible). There was a significant advantage for d-linked (which N) interrogatives (mean ratings of 4.87 vs 5.58; $F1(1,37) = 7.45$, $p < .01$; $F2(1,20) = 24.69$, $p < .001$). None of the interactions with animacy or number approached significance; the advantage for d-linked phrases was present for all types of

sentences tested. Although the difference was small and nonsignificant, the fact that the effect of d-linking was numerically greater for plural than for singular items (.85 vs .60) indicates that the d-linking effect is not simply a matter of favoring an explicitly gender-matched antecedent.

--- Table 3 about here ---

Discussion

Experiment 4 showed generally low acceptability ratings for island violation sentences, i.e., ratings were above 4.0, the mid-point between complete acceptability (1) and complete unacceptability (7). Nevertheless, d-linked sentences were rated reliably more acceptable than their non-d-linked counterparts. We attribute this effect to the ease of establishing a relation between the pronoun and the d-linked interrogative (on a par with Experiments 1 -- 3), which results in an ungrammatical but fully interpretable sentence. This interpretation assumes that in English a resumptive pronoun is, at least initially, treated like other pronouns, and prefers to find its antecedent in a discourse structure (see Sells, 1984, for discussion of intrusive pronouns).

Experiment 5

Experiment 5 tested the same materials as Experiment 4, this time in an auditory incremental grammaticality judgment study. This technique is the auditory equivalent of a visually-based technique that has frequently been shown to be sensitive to rather subtle sentence comprehension effects (e.g., Boland, 1997; Stowe, 1988). Although some have argued that the task reflects the revision of parsing analyses and the process of interpretation rather than initial parsing processes (e.g., Clifton, 1993), the incremental grammaticality judgment task seems appropriate to questions of d-linking, since they are questions of interpretation. We used an

auditory variant of this task simply to extend our observations to the spoken modality.

Methods

Materials. Two versions each of the 24 sentences used in Experiment 4 together with an additional 64 sentences (plus nine practice sentences) were recorded by a trained phonologist who was instructed to pronounce the sentences with a neutral prosody, placing only a minor intonational break before the embedded clause. In addition to the critical ungrammatical sentences of Experiment 4, the experiment included 18 sentences with acceptable but sometimes ambiguous pronouns, twelve how many question sentences, 16 complex sentences half of which had subject-verb number disagreements, 16 sentences with ambiguous temporal adverbs, and 2 filler sentences similar to the experimental sentences but containing no pronoun inside the island.

The sentences were digitized at 22kHz and stored as standard PC auditory files (.wav files) to be played to subjects in the experiment. A simple question was made up for each sentence (e.g., following “Which students/who did the teacher wonder if they had gone to the library?” the question was “What did the teacher wonder?”and the answers were “He wondered whether they had gone to the library” and “He wondered whether they had lunch.” While it might seem strange to ask a question of a question, our experimental subjects seemed to accept the task as perfectly natural.

Subjects and procedures. Sixty University of Massachusetts students were tested in individual half-hour sessions. They were instructed that they should listen to sentences with the purpose of identifying "bad, unacceptable, ungrammatical, nonsensical" sentences. As soon as they identified an unacceptable sentence, they were to pull a trigger with their left hand, and the

sentence would stop. If the sentence was acceptable, they were to pull a trigger with their right hand, and a question would appear on a video screen. They were then to pull a trigger under the correct one of two answers about the sentence they had just heard. They were told that most of the sentences were actually acceptable, but that some had two meanings and that they should choose the answer that best fit what the sentence had meant to them.

After receiving the practice list, each subject heard one of two counterbalanced lists. Each half of the Experiment 5 sentences appeared in d-linked form in one list, and in non-d-linked form in the other list. Sentences were played in individually-randomized order, and responses and reaction times were recorded.

Results

The primary results are the percentages of sentences that were accepted (vs. being classed as unacceptable). These percentages appear in Table 4, broken down by specific type of sentence as in Experiment 4.

--- Table 4 about here ---

Significantly more sentences were accepted when they had a d-linked (which-N) phrase than when they had a non-d-linked (who) word ($F1(1,59) = 44.67$; $F2(1,20) = 73.47$; $p < .001$). The pattern appeared in all number and animacy sentence categories. In particular, the size of the d-linking effect was very comparable for plural and for singular antecedents (18 vs 17%). Thus, Experiment 5 listeners, like Experiment 4 readers, were more willing to overlook the ungrammaticality of sentences with resumptive pronouns when the antecedent of the pronoun was a d-linked term than when it was a non-d-linked term.

However, listeners were more willing to accept sentences with plural than with singular pronouns (56.0 vs 49.9%; $F1(1,59) = 8.88$, $p < .01$; $F2(1,20) = 6.48$, $p < .02$). This latter tendency (which did not depend on the d-linking status of the interrogative phrase) was not seen in the Experiment 4 ratings. We are not certain what this effect means. One possibility stems from the fact that in 16 of our 24 sentences, the subject of the embedded clause was the noun immediately before the pronoun, and in the remaining sentences, the noun immediately before the pronoun was the same in number and gender as the embedded subject. A singular, gender-marked, pronoun in the Experiment 4 and 5 sentences always conflicted with the preceding noun in gender, but a plural, non-gender-marked, pronoun conflicted only in number. Even though the preceding noun is only temporarily a syntactically possible antecedent for the pronoun, our listeners may have tentatively assigned it as the antecedent. In this case, they may have sometimes rejected the sentence because of the number or gender mismatch between pronoun and this tentative antecedent. If they are more sensitive to gender-mismatches than to number-mismatches (perhaps because of the use of <u>they</u> with a singular antecedent, avoiding socially-sensitive specification of gender), rejections may have been more frequent for the gender-mismatching singular pronouns than for plural pronouns.

Reaction times were computed for "OK" responses, measured from the end of the sentence. While "OK" responses to d-linked sentences appeared to be faster than "OK" responses to non-d-linked sentences (1328 vs 1486 ms), the difference could not be tested statistically in a by-subjects analysis because of excessive missing data, and the difference was not significant in a by-items analysis ($F2(1,20) = 2.30$, $p > .10$). Ninety-two percent of the questions that were asked

following sentences were answered correctly.

Discussion

The results of the auditory study closely parallel those of the visual study (Experiment 4). The d-linked 'island violations' were accepted 62% of the time whereas the non-d-linked questions were accepted only 44% of the time.

These results fit with those obtained in Experiment 4, where the acceptability ratings were somewhat above the middle of the scale (4.0 where 7 was "unacceptable"). In Experiment 5, the grammaticality judgments suggest that both d-linked and non-d-linked island violations are questionable, with d-linked examples being marginally acceptable and non-d-linked ones being relatively unacceptable. This suggestion is consistent with evidence presented by Dickey (1996), who showed that a wh-question sentence with an ungrammatical resumptive pronoun was read faster than a sentence with a gap (grammatical trace), just in case the wh-phrase was far removed from the pronoun or trace in terms of number of clause boundaries (e.g., "Who did Bill say that Mike pretended that Al adopted (her)?"). Dickey argued that a resumptive pronoun could access the discourse representation of an antecedent if its surface form is no longer available, but that a gap could only access a more rapidly fading syntactic representation (a conclusion that supports our assumption that resumptive pronouns are deep anaphors and thus take discourse antecedents).

Numerically the plurals were more acceptable than the singulars, a difference that did not interact with d-linking status of the antecedent. This difference appeared in the speeded task used in Experiment 5, but not in the questionnaire task of Experiment 4. We suggested that it may

reflect a greater tendency to quickly reject a sentence with a pronoun that disagrees in gender with a preceding temporarily possible NP antecedent than to reject one that disagrees in number. The disappearance of the effect in Experiment 4 may be due to the fact that by the end of the sentence it has become clear that the NP in question is not in fact the antecedent of the pronoun and thus its gender or number conflict is irrelevant.

General Discussion

The results of five experiments support the notion that d-linked phrases are processed differently than non-d-linked ones. We proposed that d-linked phrases are rapidly instantiated in the discourse representation, rendering them tempting antecedents for pronouns. Hence they are chosen as antecedents more often than non-d-linked phrases (Experiments 1 and 2). Sentences where a d-linked phrase is the only available antecedent are processed more quickly than their non-d-linked counterparts (Experiment 3). Finally, ungrammatical sentences with no trace for an interrogative phrase are rated more acceptable if a pronoun inside the island can be related to a d-linked phrase than a non-d-linked one (Experiments 4-5). All of these results readily follow from an account based on the discourse properties of d-linked phrases and thus support Pesetsky's (1987) characterization of the distinction between types of interrogatives.

In principle, one might attribute the results of the first three experiments to the presence of determinate matching features on the d-linked interrogative and merely consistent features on the non-d-linked interrogative, coupled with the hypothesis that pronouns prefer antecedents with positive determinate features matching the features of the pronoun. One problem with this approach is that it fails to account for the results of Experiments 4 and 5. Even if the matching

features allowed the antecedent of the resumptive pronoun to be found in the sentence more easily, the sentence is still ungrammatical. Additional principles must be invoked to explain why d-linking induces a difference in acceptability. The most obviously appropriate such principle claims that the resumptive pronoun is not treated as resumptive at all, but simply as discourse-referential. But this is best motivated by the claim that a d-linked wh-phrase sets up a discourse entity to which a pronoun can refer, which amounts to our proposed discourse instantiation hypothesis.

Further, the assumption that pronouns prefer antecedents with positive determinate matching features is problematic. If feature matching were critical to pronoun processing, we might expect processing of a pronoun to be fast whenever feature matching unambiguously picks out a single plausible appropriate antecedent. This is not always the case. Pronouns with featurally unambiguous matching antecedents are not processed quickly if they correspond to one conjunct of a conjoined NP (Albrecht and Clifton, 1998) or if they occur in a possessive phrase (Gordon, Hendrick, Lecoux & Lang, 1999). Further, an antecedent with determinate features that match the pronoun is not invariably the preferred antecedent of the pronoun. Koh (2001) showed that a plural antecedent including all discourse participants is often preferred as an antecedent of <u>they</u> over a NP with determinate features matching the pronoun. For instance, in <u>John sang with Joe and Tim. They....</u> the preferred antecedent of <u>they</u> is the triple of John, Joe, and Tim, not the plural NP <u>Joe and Tim</u>. Further, in languages that provide a choice of pronominal form, pronouns may be preferred which do not provide a positive match with the features of the antecedent. In languages with null pronominals, the null pronoun is often preferred to an overt

pronoun with overt positive evidence for feature matching (see in particular, Carminati, in progress). Also, in unpublished questionnaire studies in English, we have shown that English readers prefer a plural pronoun over a singular for bound variable pronouns. Sixty-two percent of our subjects gave a bound variable interpretation of the plural pronoun in sentences like John and Joe say that everyone's mother loves them while only 31% gave a bound variable interpretation of the singular pronoun in John says that everyone's mother loves him, despite the fact that the superficial antecedent of the bound pronoun is the singular everyone. This suggests that if feature support is important, it may be semantic support for the number feature carried by the pronoun and not matching of the surface syntactic features of pronoun and antecedent. We suggest that the simplest, most unified and empirically best supported explanation of our data is the discourse instantiation hypothesis, based on Pesetsky's account of d-linking.

We note, however, that ultimately the source of d-linking behavior must be explained, assuming that it is not an arbitrary stipulation of English that which N' is d-linked and who is not. It is unclear at present whether the characterization of an interrogative as d-linked or not can be derived from the semantics of which. Another possibility is that the overt number marking that d-linked phrases carry makes them receive a determinate interpretation. Non-d-linked phrases, in contrast, do not have determinate number marking, but just a preferred default. For instance, Who was at the bus-stop? need not imply that only a single person was at the bus-stop (although it may invite that interpretation). Perhaps a determinate number interpretation triggers instantiation of one or more entities in discourse. Whatever its underlying source may ultimately be, d-linking is clearly an important linguistic property which guides the processor's behavior.

Appendix A

Sentences used in Experiment 1.

1. Rick knew who/which brother Janice sang a song to before he went to sleep.

2. Tom announced who/which son Mrs. Cheng gave a present to when he graduated.

3. Mike wondered who/which pilot Mrs. Smith brought a pie to when he was sick.

4. Who/Which guy did Bradley send a rifle to when he was threatened?

5. Who/Which son did Dad deliver a book to before he went on vacation?

6. Who/Which little boy did Paul tell a story to before he had an operation?

7. Dan forgot who/which widower Lisa wrote a letter to before he went to jail.

8. Who/Which postman did Edwin take some food to after he fell down the stairs?

9. Who/Which truck drive did Mr. Bronson claim apologized after he escaped?

10. Sam heard who/which shop-keeper the report indicated left before he responded to the police questions.

11. Fred discovered who/which watchman the evidence proved was home when he called the police.

12. Stanley noted who/which uncle Mary said planted tulips when he was visiting.

13. Who/Which uncle did Anthony report was rich before he went bankrupt?

14. Who/Which actor did Charles think played tricks before he left?

15. Edgar remembered who/which barber Ingrid asserted left before he got angry.

16. Who/Which schoolboy did Thomas imply read the novel while he was in Hawaii?

17. Ted reported to whom/which man Martha said that he should vote.

18. Karl could see to whom/which grandson Grandma whispered that he was being rude.

19. To whom/which steward did Mr. Shumway mention that he would be promoted?

20. To whom/which baseball player did Seth explain that he should study more?

21. Gus realized to whom/which waiter Sandra indicated that he was drunk.

22. To whom/which fireman did Andy scream that he was in danger?

23. Felix disclosed to whom/which ambassador Paula report that he must flee the country.

24. To whom/which boyscout did Bill say that he must be on time for school?

Appendix B

Sentences used in Experiment 2.

1. Rick knew who/which visitor Joan sang a song to before he went to sleep.

2. Keith noted who/which student Mrs. Cheng gave a present to when he visited.

3. Mike wondered who/which neighbor Mrs. Smith brought a pie to when he was sick.

4. Donna forgot who/which reporter Luke wrote a letter to before she went to jail.

5. Thelma asked who/which student Aaron offered a job to after she moved to town.

6. Irene heard who/which acquaintance Carl gave some money to after she got fired.

7. David asked to whom/which colleague Alison said that he should vote.

8. Kevin saw to whom/which grandchild Grandma whispered that he was being rude.

9. Gary realized to whom/which movie star Anne screamed that he was in danger.

10. Ruth wondered to whom/which columnist Bill reported that she must flee the country.

11. Jill knew to whom/which colleague Frank mentioned that she was welcome to stay.

12. Julie noted to whom/which camper Samuel signaled that she must leave soon.

13. Who/Which friend did Brian send a rifle to when he was threatened?

14. Who/Which patient did Edwin take some food to after he fell down the stairs?

15. Who/Which sibling did Peter tell a story to before he had an operation?

16. Who/Which relative did Stacy bring flowers to when she turned sixty?

17. Who/Which child did Hannah show pictures to when she came over for dinner?

18. Who/Which teenager did Mom deliver a book to before she went on vacation?

19. To whom/which coworker did Mr. Stevens mention that he would be promoted?

20. To whom/which friend did Seth explain that he should study more?

21. To whom/which employee did Larry indicate that he was drunk?

22. To whom/which individual did Paula say that she must be on time for school?

23. To whom/which acquaintance did Theresa announce that she won the lottery?

24. To whom/which 6th grader did Melinda write that she should arrive by noon?

Appendix C

Sentences used in Experiment 3 (alternate versions separated by /). ^ used to indicate division into presentation regions.

1. Rita/Rick knew who/which brother/sister Joan/Josh sang a song to^before he/she went to sleep.

2. Kathy/Keith noted who/which son/daughter Mrs./Mr. Cheng gave a present to^when he/she graduated.

3. Mary/Mike wondered who/which nephew/niece Mrs./Mr. Smith brought a pie to^when he/she was sick.

4. Who/Which guy/woman did Becky/Brian send a rifle to^when he/she was threatened?

5. Who/Which priest/nun did Elise/Edwin take some food to^after he/she fell down the stairs?

6. Who/Which little boy/girl did Polly/Peter tell a story to^before he/she had an operation?

7. Deanna/Donald forgot who/which bishop/actress Lisa/Luke wrote a letter to^before he/she went to jail.

8. Who/Which son/daughter did Mom/Dad deliver a book to^before he/she went on vacation?

9. Thelma/Thomas asked who/which nephew/niece Alice/Aaron offered a job to^after he/she got a license.

10. Who/Which Grandpa/Grandma did Stacy/Steve bring flowers to^when he/she turned sixty?

11. Irene/Isaac heard who/which barber/hostess Cass/Carl gave some money to^after he/she got fired.

12. Who/Which boyfriend/girlfriend did Hannah/Harvey show pictures to^when he/she came over for dinner?

13. Donna/David asked to whom/which barber/seamstress Alison/Andrew said^that he/she should vote.

14. To whom/which headmaster/headmistress did Mrs./Mr. Stevens mention^that he/she would be promoted?

15. To whom/which brother/sister did Sara/Seth explain^that he/she should study more?

16. Karen/Kevin saw to whom/which grandson/granddaughter Grandma/Grandpa whispered^that he/she was being rude.

17. To whom/which waitress/butler did Linda/Larry indicate^that he/she was drunk?

18. Gina/Gary realized to whom/which prince/princess Anne screamed^that he/she was in danger.

19. Ruth/Ross wondered to whom/which king/queen Beth/Bill reported^that he/she must flee the country.

20. To whom/which boyscout/girlscout did Paula/Paolo say^that he/she must be on time for school?

21. To whom/which fireman/midwife did Theresa/Timothy announce^that he/she won the lottery?

22. Jill/Jeff knew to whom/which uncle/aunt Frida/Frank mentioned^that he/she was welcome to stay.

23. To whom/which bachelor/mistress did Melinda/Matthew write^that he/she should arrive by noon?

24. Julie/James noted to whom/which boy/girl Sheila/Samuel signaled^that he/she must leave soon.

Appendix D.

Sentences used in Experiments 4 and 5

1. Who/Which students did the teacher wonder if they had gone to the library?

2. Who/Which employers did the shopkeeper want to know if they would come back after the protest?

3. Who/Which mayors did the organizer of the conference wonder if they would show up?

4. Who/Which librarians did the union organizer ask the supervisor if they would be likely to

volunteer for committee work?

5. Who/Which clients did the therapist wonder whether they would make progress?

6. Who/Which soldiers did the lieutenant ask the platoon leader if they were scared?

7. Who/Which executive did the secretaries wonder whether he would resign after the scandal?

8. Who/Which carpenter did the contractors ask the builders if he was reliable?

9. Who/Which performer did the studio deliberate whether he should continue working?

10. Who/Which plumber did Jill wonder whether he would come on the weekend?

11. Who/Which butcher did Karen ask Mary if he would cut a chicken into 16 pieces?

12. Who/Which taxi driver did Lucy wonder if he was Muslim?

13. What/Which quidelines did the inspector wonder if they should be re-evaluated?

14. What/Which vacuum cleaners did the repairman ask the boss if they could be fixed?

15. What/Which companies did the journalist want to investigate whether they fixed prices?

16. What/Which books did the principal wonder if they were too difficult for second graders?

17. What/Which cookies did the babysitter ask the cook if they could be eaten?

18. What/Which pamphlets was the teacher unsure whether they were appropriate for children?

19. What/Which rule did the parents ask the counselor whether it should be relaxed?

20. What/Which shop did Sam wonder if it would fold before January?

21. What/Which motorcycle did the rental agents wonder if it should be taken out of service?

22. What/Which board game did the children keep asking the babysitter where it was?

23. What/Which table did the man deliberate whether it could be entered in the craft show?

24. What/Which ground rule did the campers always wonder whether it could be broken?

Authors' Notes

This research was supported by grant HD-18708 to the University of Massachusetts. We would like to thank Janina Radó, Sveva Besana, Jennifer Boltuch, Katie McSheehy, Yania Basquez, and Elisabeth Villalta for their help in conducting the studies reported here. Frazier's address: Department of Linguistics, University of Massachusetts, Amherst, MA 01003. Clifton's address: Department of Psychology, University of Massachusetts, Amherst, MA 01003; cec@psych.umass.edu.

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Table 1

Proportion of choices of wh-item as antecedent of pronoun, Experiments 1 and 2

Wh-item	Embedded Questions	Matrix Questions	All Questions
		Experiment 1	
Who	.39	.42	.41
Which-N	.56	.55	.56
		Experiment 2	
Who	.40	.37	.38
Which-N	.44	.45	.45

Table 2

Mean Reading Times (ms/character), Segment 2, Experiment 3

Condition	Male	Female	Mean
Who-main	64.0	57.6	60.8
Which N-main	57.9	56.4	57.2
Who-embedded	61.5	68.3	64.9
Which N-embedded	60.6	59.0	59.8

Table 3

Mean Sentence Ratings (1 = good, 7 = terrible), Experiment 4

Sentence Form	d-linking Status	
	d-linked	non-d-linked
	(which)	(who/what)
plural animate	4.92	5.64
singular animate	4.99	5.62
plural inanimate	4.67	5.64
singular inanimate	4.88	5.44
mean	4.87	5.58

Table 4

Mean Percentage Acceptances, Experiment 5

Sentence Form	d-linking Status	
	d-linked	non-d-linked
	(which)	(who/what)
plural animate	65.6	50.0
singular animate	57.2	42.2
plural inanimate	64.4	43.9
singular inanimate	59.4	40.8
mean	61.7	44.2

Footnotes

1. The five experiments reported in this paper tested only normal adults. It has been claimed that agrammatic aphasics can represent nonreferential ('government') chains but not referential ('binding') chains, see Avrutin and Hickok (1993) and Hickok and Avrutin (1995). We think this is an interesting possibility, but we also think that it needs further investigation before it can be considered seriously. There is some evidence that the claimed finding may not be secure. Frazier and McNamara (1995) tested agrammatic aphasics on referential and nonreferential chains in grammatical and ungrammatical (resumptive pronoun) sentences. They did not find any overall advantage for nonreferential chains, nor was performance worse for chains than for other dependencies involving long distances, such as reflexives bound by null pronouns or constructions with "respectively."

2. To the best of our knowledge, English provides no way to eliminate the link between explicit number-marking and <u>who</u> vs. <u>which-N</u>. While we are content to accept explicit number-marking as one possible basis of d-linking, it would be interesting to investigate other languages which contain distinct singular and plural forms of the interrogative pronoun.