Intuitive knowledge of linguistic co-reference

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Abstract

The research reported here is a systematic investigation of what competent, native speakers of English, naive to contemporary syntactic theory, judge to be grammatically acceptable patterns of co-reference involving names and pronouns. Its central goal is the specification of syntactic factors that influence co-reference within and between sentences. The results show that naive subjects have consistent intuitions of grammaticality that agree with some principles of contemporary binding theory. The results also show that naive subjects diverge substantially from syntactic theorists in other judgments of grammaticality. In particular, subjects have strong intuitions that reflexives and pronouns are in complementary distribution, a fact that supports contemporary syntactic theory. Beyond that domain, subjects' judgments of co-reference in name-pronoun, name-name, and pronoun-name sequences are systematically influenced by syntactic structure in ways that are not consistent with syntactic theory. Co-reference in name-pronoun sequences is generally quite acceptable but becomes more acceptable as the syntactic prominence of the name increases. Co-reference in name-name sequences is only moderately acceptable and becomes less acceptable as the syntactic prominence of the first name increases. Co-reference in pronoun-name sequences is generally unacceptable and is only weakly influenced by the kinds of syntactic prominence that affect other relations of co-reference. We account for these results through the elaboration of a model of the process by which syntactic representations are mapped onto a representation of discourse capable of expressing generalizations about co-reference both intra-sententially and inter-sententially. ©1997 Elsevier Science B.V.

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1. Introduction

Linguistic reference is the mechanism by which language users make contact with worlds of meaning, thereby providing a crucial link between linguistic forms and semantic domains that are external to language. Linguistic *co-reference* is the mechanism by which two linguistic forms refer to the same semantic entity. Patterns of co-reference are strongly influenced by linguistic factors such as the form of referring expressions, the syntactic structure of sentences, and the local organization of discourse. The role of these linguistic factors can be conceptualized in two ways: They can be seen as purely linguistic phenomena that only affect the truth-conditional semantic interpretation of language through their provision of information about which expressions refer to the same entity. Alternatively, their role in organizing linguistic forms can be seen as contributing to the organization of a discourse model whose truth-conditional interpretation embodies the created meaning of a linguistic communication. We take the latter view. In this paper, we attempt to contribute to it through a systematic empirical investigation of patterns of acceptable co-reference involving names and pronouns, and through the elaboration of a model of discourse processing and representation as an explanation of those patterns.

In conducting this research, we cross disciplinary boundaries in substantial ways in our choices of evidence, method and theory. As evidence, we employ intuitions about the grammaticality of sentences; such intuitions have been the primary data of contemporary generative linguistics. However, in contrast to common linguistic practice, we observe elementary methodological precautions of experimental psychology by using subjects who are naive to our hypotheses, controlling presentation of stimulus materials, and performing statistical analyses on the patterns of grammaticality judgments that we obtain. As a theoretical framework, we employ constructs developed in philosophy and computer science that characterize the dynamic processes by which discourse representations are created from language. This emphasis on the processing of language is consistent with the theoretical focus of contemporary psycholinguistics, but is tangential to the approach of generative linguistics that attempts to explain patterns of language.

The studies presented here arose from the goal of integrating knowledge of how referring expressions participate in the structure of local discourse segments and in the structure of sentences. Research on centering theory (Grosz et al., 1983, 1986, 1995; Gordon et al., 1993) has identified circumstances in which discourse coherence is disrupted by co-reference between sentences using full expressions (such as names) as compared to reduced expressions (such as pronouns). This phenomenon is superficially very similar to constraints on co-reference within sentences using full expressions; these within-sentence constraints are addressed by Chomsky's (Chomsky, 1981) Binding Theory, a central work in generative accounts of syntactic co-reference. The current studies were designed to assess the similarity of inter-sentential and intra-sentential co-reference. We wished to examine whether a construct of syntactic prominence, as explored inter-sentential-

ly in Gordon et al. (1993), influenced intra-sentential co-reference, as studied in Chomsky (1981). As our work progressed, it became clear that some of the results conflicted with empirical claims of the Binding Theory. Accordingly, our studies took on a second goal of more accurately characterizing the grammatical intuitions of naive subjects. To provide a context for our studies, we first review some essentials of the Binding Theory, of more psycholinguistically oriented research on co-reference, and of centering theory.
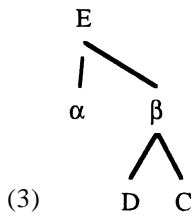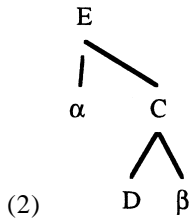
2. Basic binding theory

The notion of co-reference (or anaphora) holds a privileged position in linguistic theory. Indeed, one way to understand the development of the principles and parameters approach to generative grammar (Chomsky, 1981, 1986) is to think of it as developing a theory of anaphora. This approach seeks to characterize universal aspects of syntactic structure in terms of formally expressed principles, and to explain language variation in terms of the setting of parameters in a way that is constrained by the principles. The syntactic structures emerging from this perspective have been motivated in good part to explain the distribution of the various classes of anaphora that differ in how they are *bound* by their *antecedents* (e.g., Larson, 1988, 1990). Binding is a relation where one linguistic expression is coindexed with another, representing the fact that they refer to the same entity. In traditional grammar, an antecedent is a linguistic expression the meaning of which another expression recapitulates.

The construct of c-command (Reinhart, 1976, 1981) has been crucial to this theoretical development; its definition is shown in (1).

(1) α c-commands β if and only if the first branching node above α contains β.

Intuitively, c-command defines a relation of prominence between two syntactic elements, α and β. α is prominent in the sense of c-command if the first phrase that dominates it also dominates β. This notion includes but is broader than the notion of constituency in standard phrase structure grammars.[1] In (2) α c-commands β, but β does not c-command α. In (3) α c-commands β and β c-commands α.

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[1] By exclusively employing rewrite rules such as $\gamma \rightarrow \alpha\beta$, phase structure grammars define a relation between α and the first node γ that dominates α; c-command defines the relation between α in (1) and any other constituent β that is dominated by all the same nodes as α.

```
        E
       /\
      /  \
     α    C
         /\
        /  \
(2)    D    β
```

```
        E
       /\
      /  \
     α     β
          /\
         /  \
(3)     D    C
```

The construct of c-command, in combination with different forms of referential expressions, forms the basis of the three principles of the Binding Theory of Chomsky (1981).
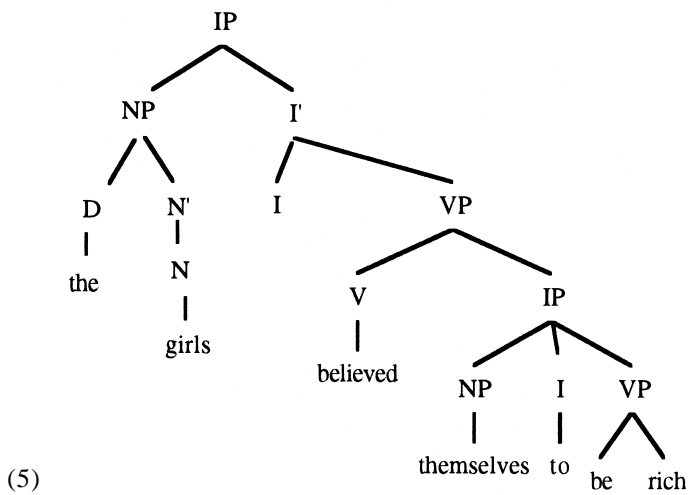
Principle A applies to "anaphors", a class of pronominal elements including reflexives and reciprocals. It states that an anaphor requires a c-commanding antecedent in its "governing category", which can be defined informally as the smallest noun phrase or clause that the element appears in.[2] Sentence (4), which has the structure shown in (5),[3] conforms to this principle and is grammatical.

(4)   the girls believed themselves to be rich

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[2] An early formal definition of governing category can be found in Chomsky (1981). More sophisticated definitions are considered in Chomsky (1986) and Rizzi (1990).
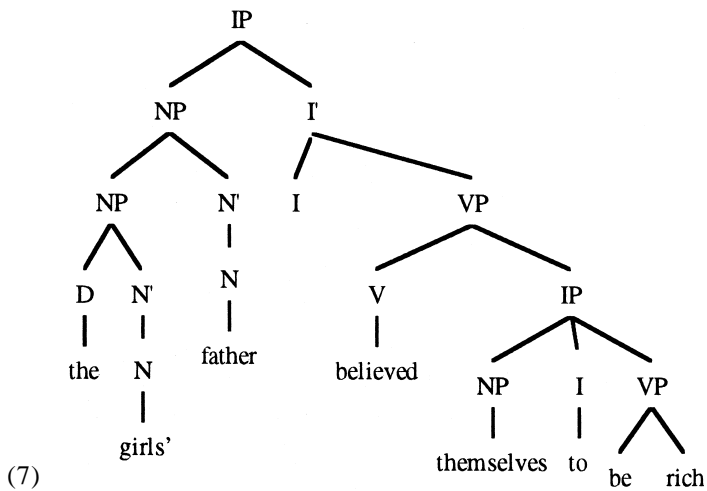
[3] The notation that we use on the syntactic tree is consistent with general practice in the principles and parameters approach to syntax. The labeled nodes in the tree are phrase markers. The labels have the following general meaning:

IP	Inflectional phrase (a phrase that encodes temporal information of the clause)
I	Inflection (temporal affix or tense)
NP	Noun phrase
D	Determiner
N	Noun
VP	Verb phrase
V	Verb
'	This diacritic (pronounced "bar") indicates a subphrase of the major phrase

(5)

```
                        IP
                   ╱         ╲
                 NP            I'
                ╱  ╲          ╱    ╲
              D     N'      I        VP
              │     │              ╱     ╲
             the    N            V         IP
                    │            │        ╱ │ ╲
                  girls       believed  NP   I   VP
                                        │    │   ╱╲
                                   themselves to be  rich
```

Sentence (6), which has the structure shown in (7), does not conform to this principle because the anaphor ("themselves") lacks a c-commanding antecedent ("girls" is not c-commanding due to the branching of the subject NP). It is not grammatical.

(6)   *the girls' father believed themselves to be rich

(7)

```
                         IP
                    ╱          ╲
                  NP             I'
                ╱    ╲          ╱    ╲
              NP      N'      I        VP
             ╱  ╲     │              ╱     ╲
           D    N'    N            V         IP
           │    │     │            │        ╱ │ ╲
          the   N   father      believed  NP   I   VP
                │                          │    │   ╱╲
              girls'                  themselves to be  rich
```

Principle B applies to pronominals, such as *she*, *he*, *it*, which have been claimed to be in complementary distribution with anaphors. It states that pronominals cannot appear in the same governing category with a c-commanding antecedent.

Accordingly, sentence (8), with the structure shown in (9), is not grammatical if
"girls" and "them" are interpreted as co-referential; these expressions are forced
to refer to different sets of individuals.[4]

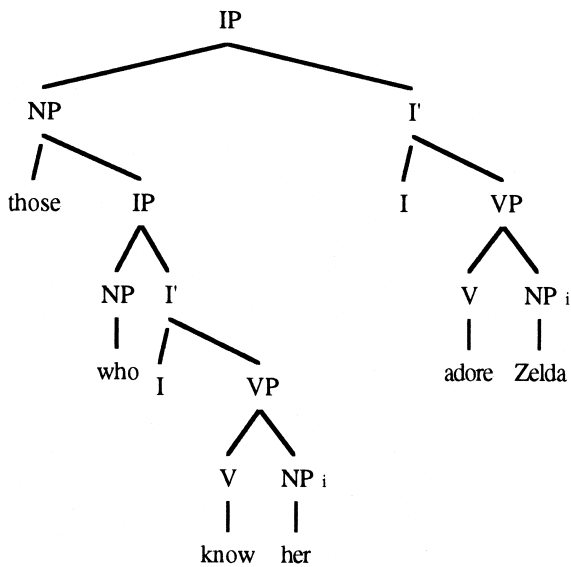(8)   *the girls$_i$ believed them$_i$ to be rich

(9)
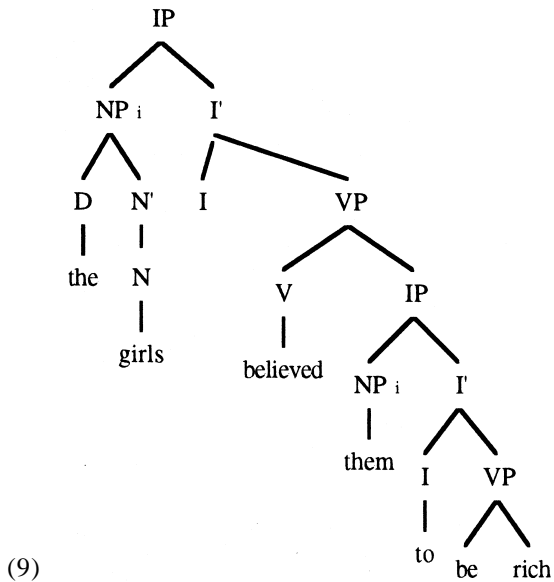
Principle C applies to referring expressions (or R-expressions), a class that
includes names. It states that R-expressions cannot have a c-commanding
antecedent. The contrast between sentences like (10) and (11), taken from
Reinhart (1981), is often cited to illustrate this principle. Co-reference is excluded
in (10) because *she* c-commands the name *Zelda*; (11) admits co-reference as
possible (although not necessary) because *her* does not c-command *Zelda*. It
should be noted that Principle C takes no account of the form of the antecedent; it
would be violated equally if the *she* in (10) were replaced by the name *Zelda*.

(10)   *She$_i$ adores Zelda's$_i$ teachers.

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[4] Sentence (8) illustrates two important conventions of linguistic notation. The "*" at the beginning
of the string indicates the judgment that it is not grammatically acceptable. The subscripted indices
beneath "girls" and "them" indicate intended reference. Since "girls" and "them" both have the
same index, they are intended to be interpreted as co-referential. Under that interpretation it is judged
as grammatically unacceptable.

IP
NP i I'
she I VP
V NP
adores NP i N'
N
Zelda's teachers
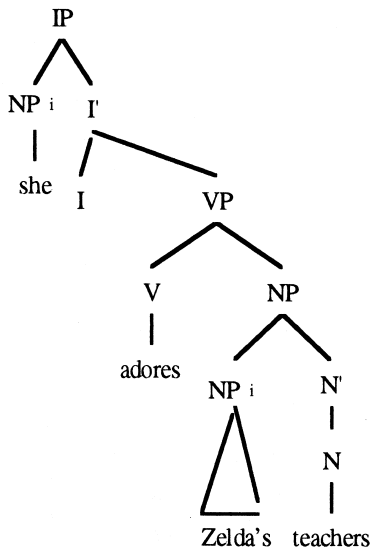
(11)   Those who know her$_i$ adore Zelda$_i$.

IP
NP I'
those IP I VP
NP I' V NP i
who I VP adore Zelda
V NP i
know her

Anaphors and pronominals have commanded a great deal of theoretical attention because their distribution is highly restricted by the notion of governing category, a locality constraint on how far they can, or cannot, be separated from their antecedents. Names, because they do not show such locality constraints, have been considered less puzzling and have received less attention. The theoretical attention they have received has mostly concerned whether even the modest restriction formalized in Principle C is empirically true and whether it should have the same

grammatical status as Principles A and B of the Binding Theory.[5] The locality constraints on anaphora are important because they have been considered strong candidates to be independent, possibly innate, principles of Universal Grammar. Independent of this contention, the locality constraints have a theoretical use within principles and parameters theories of syntactic structure because they are often used to limit the class of possible syntactic movements such as passivization.

Binding theory has been elaborated and modified considerably since the basic works of Chomsky (1981) and Reinhart (1976), (1981). These elaborations have addressed issues such as: the correct characterization of the domain relevant to Principles A and B (Hestvik, 1990; Huang, 1982a,b), the correctness of the assertion that pronominals and anaphors are in complementary distribution (Chomsky, 1986), the unification of domains of movement and anaphora (Lebeaux, 1985), and the class of elements covered by Principle C (Cinque, 1990; McCloskey, 1990; Stowell and Lasnik, 1991). There has been some controversy, prompted by Reinhart (1981) and Grodzinsky and Reinhart (1993), over whether the binding of anaphors should be conflated with issues of co-reference involving names and pronouns by representing all these relations as uniform instances of coindexing. However, these elaborations of Binding Theory and their accompanying debates have not reduced the centrality of the basic principles that we have outlined here.

3. Experimental studies of co-reference

3.1. Co-reference within sentences

While the theoretical concerns of generative linguistics have led to a great deal of study of patterns of acceptable co-reference between names and pronouns, a theoretical focus on processes of comprehension has led psycholinguists to examine quite different questions (Carlson and Tanenhaus, 1989; Garnham, 1989). These differing concerns have to some extent resulted in linguistic and psycholinguistic research on co-reference proceeding as unrelated enterprises, though there have been some studies of the role of binding constraints on comprehension (Badecker and Straub, 1994; Nicol and Swinney, 1989). In addition, some experimental results on comprehension can be seen as contributing to an understanding of patterns of co-reference. To this end, we will briefly review research on the interpretation of syntactically ambiguous pronouns and on the way in which different kinds of referring expressions contribute to the coherence of discourse.

One notable feature of the binding principles outlined above is that only Principle A (covering anaphors such as reflexives) specifies the identity of the antecedent of a referring expression. In contrast, Principles B and C specify

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[5] The issue of whether Principle C is empirically correct is raised in (Evans, 1980).

disjoint reference, what an antecedent cannot be. Perhaps because these principles seem compelling, psycholinguists interested in the interpretation of ambiguous pronouns have for the most part examined constructions, for example, (12), involving co-reference that is "accidental" in the sense that none of these principles apply.

(12)   John told Bill that he deserved the prize.

In these cases, co-reference is seen as emerging not from linguistic structure, but from the intention to communicate certain meanings. For (12), one could easily imagine differing scenarios in which *he* should co-refer with *John* or with *Bill*, and a secure interpretation of the pronoun can only be achieved using knowledge about the communicative situation. While this is ultimately true, experiments on sentence processing have shown that there are strong preferences to assign initial default interpretations to such pronouns based on syntactic structure. For example, these experiments would indicate that the pronoun *he* in (12) is initially interpreted as co-referential with *John*. Such interpretive preferences have been characterized in different ways: as a parallel function bias (Sheldon, 1974; Grober et al., 1978), a subject-assignment bias (Crawley et al., 1990), or a more general prominence bias (Gordon and Scearce, 1995). These studies show that there are systematic effects of syntactic structure on co-reference beyond the domains that have been characterized by traditional Binding Theory.

Experimental studies of the processing of ambiguous pronouns have involved attempts to measure comprehension processes as they occur. Experimental studies of co-reference in child language acquisition have focused on the outcome of language comprehension, using techniques like sentence-picture matching or enactment with puppets to see what interpretations children derive from sentences. Some researchers have claimed to have shown that Binding Theory is corroborated (Lust, 1986; Solan, 1983; Crain and McKee, 1985; Grimshaw and Rosen, 1990), although others raise problems related to Principle B (Wexler and Chien, 1985; Chien and Wexler, 1987).

3.2. Co-reference between sentences

The effect of patterns of co-reference on coherence of discourse has also been the object of considerable study. It is widely believed that having successive sentences make reference to common entities is an important semantic basis of local discourse coherence (e.g., Kintsch and van Dijk, 1978). In addition, the centering theory of Grosz et al. (1983), (1986), (1995) has contended that the form of referring expressions is critical to having this kind of semantic coherence emerge. According to centering theory, each sentence in a locally coherent discourse has a single entity, the backward-looking center, that provides a link back to the previous sentence. The backward-looking center must be realized as a pronoun for this link to be effective. Experimental research on language comprehension has supported these contentions (Gordon, 1993; Gordon et al., 1993;

Gordon and Chan, 1995), and has shown that the syntactic function of an entity is critical in determining its contribution to coherence.

Centering theory's prescription that the backward-looking center must be realized as a pronoun has similar consequences to the proscription against use of names (or R-expressions) offered by Principle C of the Binding Theory. This is because both centering theory and Principle C indicate that names should not be used if co-reference is intended with a preceding referring expression that occupies a specific structural position. Research on centering has shown that names impede reading when they co-refer with an expression that is the subject of the preceding sentence, an effect that has been interpreted as being due in part to the syntactic prominence of the subject (Gordon et al., 1993). Principle C of the Binding Theory blocks the use of names that co-refer with a preceding expression in the sentence that is in a c-commanding position. This conceptual convergence prompted our original interest in assessing the similarities between inter-sentential and intra-sentential co-reference. The possibility of integrating notions of centering and binding becomes clear when it is noted that the subject NP of a sentence typically c-commands all other NPs in the sentence, suggesting that inter- and intra-sentential effects of syntactic prominence on co-reference have a similar basis.

4. Overview of the experiments

Studies by psycholinguists clearly have provided some useful information about co-reference, but as we noted above this information has not been integrated with linguistic analyses. The greatest integration comes in the area of language development studies, which examine the outcome of co-referential interpretation. One reason for this is that the study of outcomes of co-referential interpretation yield data that are more similar to the intuitive judgments favored by generative linguists than are the processing measures used in experimental research on language comprehension by adults. With some important exceptions (e.g., Carroll et al., 1981; Clifton and Odom, 1966; Gerken and Bever, 1986), there is a surprising absence of systematic experimental studies of intuitions of syntactic well-formedness that meet even minimal standards of experimental rigor in terms of controlled presentation of stimulus materials and tests of the statistical generality of effects across identifiable subject populations. This absence probably stems from the sentiment of generative linguists that the trappings of experimentation reveal nothing not already available to introspection, and that of psychologists that intuitions of grammaticality are not valuable objects of study, perhaps because they are not seen as shedding light on language processing. We believe that both these sentiments are wrong; intuitions of grammaticality are valuable data but they should be studied carefully.

In this article, we use elementary tools of experimental psychology to explore some of the central patterns of acceptable co-reference involving names and pronouns that have been of concern in theoretical linguistics. Our initial goal was to examine whether the acceptability of intra-sentential co-reference was in-

fluenced by syntactic prominence of the sort that had been found to play a role in inter-sentential co-reference (Gordon et al., 1993). As the studies progressed, we adopted an additional goal of describing the extent to which judgments of grammaticality that are accepted in the linguistics literature accurately describe the judgments of naive subjects. Six experiments are reported in which native English speakers are asked to judge whether stimulus sentences would be grammatically acceptable if certain specified expressions were interpreted as co-referential. The results of the experiments provide some evidence supporting the theoretical construct of c-command so central to the principles and parameters view of linguistic structure. They also indicate severe empirical limitations on the validity of Principle C of binding theory, specifically that it has a different status from Principles A and B. Our data on Principle C led to a reinterpretation of c-command that takes it to be a consequence of how syntactic representations are mapped onto a discourse representation that functions as the interpretation of a sentence. This reinterpretation provides the basis for an integration of the linguistic organization that operates within sentences and between sentences. In the General Discussion of this paper we will outline how such an integration could occur.

EXPERIMENT 1

This experiment examines the accuracy of Principle C of Binding Theory in characterizing the grammaticality judgments of competent, native English speakers who are naive about contemporary syntactic theory. It does so for a limited, but basic, set of sentences, for which acceptability judgments about the possible co-reference of noun phrases are systematically obtained. Table 1 lists the kinds of configurations that were investigated and a sample sentence for each. Two factors were manipulated: (1) the type of NP sequence (name-pronoun, name-name, or pronoun-name), and (2) whether the first referring expression c-commanded the second. According to Binding Theory, co-reference should always be possible when the first NP is a name and the second is a pronoun. With other types of NP sequences co-reference should be possible when there is not a c-command relation between the NPs, but should be impossible when there is such a relation. This characterization was examined by asking subjects whether co-reference was possible for the different NP configurations with and without c-command. By examining the acceptability of these configurations of referring expressions, we can address the following questions: (1) What is the effect of c-command,

Table 1
Sample stimuli for Experiment 1

NP$_1$	NP$_2$	C-command	Sample sentence
Name	Pronoun	No	**John's** roommates met **him** at the restaurant.
Name	Pronoun	Yes	**John** met **his** roommates at the restaurant.
Name	Name	No	**John's** roommates met **John** at the restaurant.
Name	Name	Yes	**John** met **John's** roommates at the restaurant.
Pronoun	Name	No	**His** roommates met **John** at the restaurant.
Pronoun	Name	Yes	**He** met **John's** roommates at the restaurant.

independent of left-to-right precedence, on the binding of names? (2) Do the same principles that govern co-reference between two names govern co-reference between a pronoun and a name?

In addition to examining these issues which arise directly from the Binding Theory, we also investigated whether the acceptability of co-reference was influenced by whether the antecedent expression was located within the subject of the sentence. The results of reading time experiments on inter-sentential co-reference, conducted to test aspects of centering theory, have shown that repeating a name is especially disruptive when the first occurrence of the name was in the role of grammatical subject (Gordon et al., 1993; Gordon and Chan, 1995). If similar principles govern both intra-sentential and inter-sentential co-reference, then this finding from centering theory leads to the expectation that disjoint reference in name-name sequences ought to be greatest when the antecedent is the subject of the sentence. This possibility is tested by including sentences in which the antecedent is in the subject (top half of Appendix A) or not in the subject (bottom half of Appendix A).

5. Method

5.1. Subjects

Forty-five University of North Carolina students in an Introduction to Language class completed the experiment as part of a classroom exercise. The students had been exposed to the systematic study of language, but had not yet studied syntax. The instructors of the sections were asked to note the questionnaires of any students who were not native speakers of English. The data from such subjects were not included in the analyses.

5.2. Stimuli

There were six versions of each of the six referential configurations. These are shown in Appendix A. The six versions include antecedents that were in the subject of the main clause of the sentence and ones which were not.

5.3. Procedure

Subjects were presented with a two-page handout. The first page instructed subjects on the task, telling them that they were to judge whether it was possible for two expressions to refer to the same person. The instructions also reminded subjects that there are no correct answers in the descriptive study of language and introduced them to the phenomenon of allowable and unallowable co-referential NPs. This was done with two sample sentences: one where (in our judgment) a name and a pronoun could clearly be co-referential, and a second where they could not. The noun phrases whose co-reference was to be considered were printed in boldface. The second page contained the 36 stimulus sentences arranged in a

pseudo-random order. Each sentence was accompanied by a check-off to indicate whether it would be acceptable if the boldfaced NPs it contained were co-referential. Each subject made a single judgment on each sentence, and across subjects six different pseudo-random orderings of the sentences were used. The entire procedure took between 5 and 10 minutes.

6. Results

Table 2 shows the proportion of acceptable sentences as a function of the three types of NP sequences, and of whether there was a c-command relationship between the expressions. A repeated-measures analysis of variance was performed with these two factors. It showed there was a substantial main effect of form of the referring expressions on acceptability, $F(2, 88) = 126.5$, $p < .001$. There was also a significant main effect of the c-command relationship, $F(1, 44) = 4.2$, $p < .05$. Moreover, there was a significant interaction between form of referring expressions and c-command relation, $F(2,88) = 7.4$, $p < .005$. A series of post hoc contrasts, adjusted by the Bonferroni method, was conducted in order to localize the effect of c-command within the sequences of referring expressions. Sentences in the name-name condition were significantly less acceptable when the first NP c-commanded the second NP, $t(44) = 3.98$, $p < .001$. C-command did not have a significant effect in either of the other sequences: name-pronoun ($t(44) = 2.2$, $p > .05$) or pronoun-name ($t(44) = 0.5$, $p > .5$).

Type of antecedent (within subject or outside of subject) did not interact significantly with c-command for name-pronoun sequences ($t(44) = 1.63$, $p > .10$) or for pronoun-name sequences ($t(44) = 0.96$, $p > .25$). This interaction was significant for name-name sequences ($t(44) = 3.06$, $p < .01$), with c-command having a greater effect on disjoint reference when the antecedent was within the subject than when it was not. Individual contrasts showed that c-command had a significant effect for antecedents in the subject of the main clause, $t(44) = 4.21$, $p < .001$, but fell short of significance when the antecedent was not in the subject of the main clause, $t(44) = 1.66$, $p > .10$.

Table 2
Overall results for Experiment 1. The table shows the proportion of acceptable sentences as a function of c-command relation, type of NP sequence, and location of the antecedent

	No c-command		C-command	
	NP_1 (name)	NP_1 (pronoun)	NP_1 (name)	NP_1 (pronoun)
Antecedent in subject				
NP_2 (name)	.37	.28	.17	.25
NP_2 (pronoun)	.98		.99	
Antecedent not in subject				
NP_2 (name)	.37	.18	.31	.19
NP_2 (pronoun)	.88		.93	

7. Discussion

The results of the experiment show that the judgments of competent English speakers are in agreement with some of the basic principles of Binding Theory, but diverge considerably from them as well. The subjects were generally quite accepting of possible co-reference in the name-pronoun condition, which is consistent with the prescriptions of Principle B of Binding Theory that allows co-reference of a pronoun and an NP which is not in its governing category. Subjects also showed some conformity with the prescriptions of Principle C in the cases where a name is to be coindexed with another name. This was more frequently judged acceptable when there was no c-command relation between the NPs than when there was one. While this pattern held for every stimulus sentence and was statistically significant overall, it was largest for cases where the c-commanding entity was the subject of the sentence; this was the only sentence type for which the effect of c-command was individually significant. Interestingly, subjects are less accepting than Binding Theory suggests they should be of co-referential interpretation of two names when there is no c-command relation between them.

Naive subjects diverge substantially from Binding Theory in their judgments of the acceptability of co-reference between a name and a pronoun that precedes it. Co-reference was generally judged as unacceptable for these sentences, and these judgments did not depend on whether the pronoun c-commanded the name. According to Principle C of Binding Theory, a pronoun and name may be co-referential if the pronoun precedes the name but does not c-command it; co-reference is not allowable if the pronoun c-commands the name. The naive subjects' judgments provided no evidence that c-command had any effect on the acceptability of co-reference for pronouns preceding names. This is surprising given assertions of the grammatical acceptability that one finds in the linguistics literature for co-reference of this sort.[6] Further doubt is cast on Principle C by the finding that the acceptability of co-reference between two names is influenced by

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[6] It is easy to turn up quotes like the following:

Let us turn now to principle (C), which asserts that R-expressions are free. For names, this gives the familiar properties, as illustrated in (1) [numbering changed from original]:

(1) (i)   he said that John would win
     (ii) John said that John would win

Where there is no emphatic stress, these are understood with the embedded occurrrence of John distinct in reference from the matrix subject. There is, in fact, a strong tendency to take names to be distinct in reference even apart from c-command, a matter that I will not pursue [footnote omitted]. (Chomsky, 1981, p. 193)

The backwards condition has little to say directly about backwards pronominalization in such cases. Observe for instance that facts like

whether they have a c-command relationship, while the judgment of co-reference between a name and a preceding pronoun is not. Principle C takes no account of the form of the antecedent when characterizing the allowable binding of a name. Thus, it cannot account for this dissociation.

Naive subjects also diverge from Binding Theory in that c-command had a larger effect on the acceptability of co-reference in name-name sequences when the antecedent was in the subject NP of the main clause than when it was not; nothing in the Binding Theory as it is traditionally formulated predicts this pattern. However, this result was expected based on studies of inter-sentential co-reference (Gordon et al., 1993; Gordon and Chan, 1995). These studies have been interpreted within the framework of centering theory as indicating that entities introduced into a discourse by expressions in syntactically prominent positions resist subsequent reference by full referring expressions. On this account, the subject is the most syntactically prominent NP in a sentence and accordingly the entity it realizes resists subsequent reference by a name.

In summary, the results support developing a concept of syntactic prominence that can be applied to inter-sentential co-reference as studied in centering theory and intra-sentential co-reference as studied in the Binding Theory. Quite strikingly, the results challenge Principle C of the Binding Theory, which addresses co-reference between a referring expression (such as a name) and an antecedent expression. This challenge is most severe in the case where a name is to be interpreted as co-referential with a preceding pronoun. The next experiment

    a.   ?His$_i$ father hates John$_i$.
    b.   *He$_i$ hates John$_i$'s father.
    c.   I spoke to his$_i$ mother about Harry$_i$.

are not characterized significantly by this condition alone. (Postal, 1971, p. 24)

Consider (2 through 4) [numbering changed from original]:

(2)   His father hates John.
(3)   His father hates someone.
(4)   Who does his father hate?

Purported co-reference between *his* and *John* is possible in (2) but pronominal binding is impossible in both (3) and (4). (Higginbotham, 1980, p. 687)

These examples, as well as Hendrick (1988), make assertions about acceptable co-reference that are at odds with our findings, particularly those concerning non-c-commanding pronouns that precede names. The syntactic constructions offered by these authors overlap considerably with our stimuli, for example, in the use of possessives (Chomsky, 1988; Higginbotham, 1980; Postal, 1971; van Riemsdijk and Williams, 1986) and of relative clauses (Lasnik, 1976; Reinhart, 1981). The bit of doubt expressed by Postal's (Postal, 1971) question mark does not appear in the writings of the other theorists. Similarly, Chomsky's (Chomsky, 1981) observation on the general awkwardness of repeating names does not find its way into his formal treatment of binding.

examines whether there are any circumstances where names can be interpreted co-referentially with a preceding pronoun.

EXPERIMENT 2

C-command is considered appealling because it provides a simple unitary account of allowable co-reference in terms of syntactic structure without relying on any notions of left-to-right order in a string of words (Reinhart, 1976; Chomsky, 1981). The results of the first experiment show that this exclusively structural account is not accurate and that left-to-right order is critical to co-reference in a variety of grammatical constructions. In this experiment we examine whether there are other grammatical constructions which do allow co-reference in pronoun-name sequences. In particular, we examine the acceptability of co-reference between a name and a non-c-commanding pronoun when the pronoun occurs in a preposed adjunct phrase,[7] as shown in Table 3. This construction is examined because studies on binding in the child language development literature indicate a strong c-command effect in such structures and because of our intuition that pronouns in preposed phrases do not immediately receive a full interpretation until the main clause of the sentence has begun. This suspension of interpretation may make the pronoun available for subsequent co-referential interpretation with a name.

8. Method

8.1. Subjects

Forty-eight subjects from the same population as before participated in the experiment. None had participated in the previous experiment.

Table 3
Sample stimuli for Experiment 2

NP$_1$	NP$_2$	C-command	Sample sentence
Name	Pronoun	No	Before **Susan** began to sing, **she** stood up.
Name	Pronoun	Yes	**Susan** stood up before **she** began to sing.
Name	Name	No	Before **Susan** began to sing, **Susan** stood up.
Name	Name	Yes	**Susan** stood up before **Susan** began to sing.
Pronoun	Name	No	Before **she** began to sing, **Susan** stood up.
Pronoun	Name	Yes	**She** stood up before **Susan** began to sing.

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[7] Adjuncts are phrases that semantically modify the basic event represented in the main clause. Semantically, they are predicates of that event. See, for example, Parsons (1990) and Higginbotham (1985).

8.2. Stimuli

Six referential configurations (shown in Table 3) were created that were analogous to those used in the previous experiment. Each sentence contained an adjunct phrase, and the c-command relationship between the NPs was manipulated by whether this phrase was preposed (as in the first sample stimulus in Table 3) or postposed (as in the second sample stimulus in Table 3). There were four versions of each of the six referential configurations. Two of these involved adjuncts that were clausal adjuncts, and two involved adjuncts that were prepositional phrase adjuncts. A complete listing of the stimuli is given in Appendix B.

8.3. Procedure

The procedure was the same as in the previous experiment.

9. Results

Table 4 shows the proportion of acceptable sentences as a function of the three types of NP sequences, and of whether there was a c-command relationship between the NPs. A repeated-measures analysis of variance showed there was a substantial main effect of type of NP sequence on acceptability, $F(2, 94) = 75.4$, $p < .001$. There was also a significant main effect of the c-command relationship, $F(1, 47) = 231.6$, $p < .001$. Moreover, there was a significant interaction between type of NP sequence and c-command relation, $F(2, 94) = 244.0$, $p < .001$. A series of post hoc contrasts, adjusted by the Bonferroni method, was conducted in order to localize the effect of c-command within the types of NP sequences. Sentences in the name-pronoun condition were significantly more acceptable when the first NP c-commanded the second NP, $t(47) = 3.51$, $p < .005$. Sentences in the name-name condition were significantly less acceptable when the first NP c-commanded the second NP, $t(47) = 4.57$, $p < .001$, as were sentences in the pronoun-name condition, $t(47) = 27.8$, $p < .001$.

Table 4
Overall results for Experiment 2. The table shows the proportion of acceptable sentences as a function of c-command relation and type of NP sequence

	No c-command		C-command	
	NP_1 (name)	NP_1 (pronoun)	NP_1 (name)	NP_1 (pronoun)
NP_2 (name)	.49	.88	.31	.04
NP_2 (pronoun)	.90		.99	

10. Discussion

The results of the experiment clearly show that there are syntactic structures in which naive subjects accept co-reference of a name and a preceding pronoun; 88% of their judgments showed acceptance of co-reference in pronoun-name sequences where c-command was eliminated by preposing the adjunct phrases. This allows us to reject the hypothesis that naive subjects simply use a linear left-to-right rule where a pronoun and name cannot co-refer if the pronoun precedes the name. Rather, it is very clear that syntactic structure plays a crucial role in enabling this kind of co-reference; when the preceding pronoun c-commands the name, as occurs when the adjuncts are postposed, then only 4% of the judgments accept co-reference.[8] The patterns of possible co-reference in pronoun-name sequences that are judged acceptable in this experiment match up nicely with those that were recorded by Carden (1982) in a study of naturally occurring pronoun-name co-reference (or ''backwards anaphora''). The overwhelming majority of his examples involved adjuncts or adjunct-like constructions.[9] Thus, we find that the intuitive judgments we collected are consistent with what is known about usage of pronoun-name sequences. Neither of these empirical sources support Principle C of Binding Theory.

With regard to co-reference in name-name sequences, the results of this experiment are consistent with those of the previous experiment. Co-reference of names was more frequently judged acceptable when there was no c-command relation between the names as compared to when there was. The use of an additional set of sentence types in the current experiment adds generality to the first experiment. Once again, the findings suggest that antecedent names and pronouns behave differently. Pronoun-name sequences in a c-command relation were much less acceptable than comparable name-name sequences in a c-command relation. This is inconsistent with Principle C where the antecedent's form is irrelevant.

Together, the first two experiments show that naive subjects' judgments of allowable co-reference are sensitive to grammatical structure, but are not consistent with the Binding Theory's Principle C. The next experiment examines whether naive subjects' judgments are consistent with Principles A and B.

EXPERIMENT 3

The goal of this experiment was to investigate naive subjects' grammaticality

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[8] Similar evidence is reported in the language development literature for children in act-out experiments with dolls (Solan, 1983).

[9] Carden (1982) gives 25 examples. Of these, 21 involve pronouns in non-argument position (19 in adjuncts and 2 in other A′ position). Of the remaining four, two occur in newspaper headlines, one potentially refers to an earlier point in the discourse, and a single example is a possessive pronoun preceding a co-referential NP. The possessive is embedded in a prepositional phrase that precedes a verb expressing a psychological state. It is possible that these factors help to make this rare usage felicitous.

Table 5
Stimuli and results for Experiment 3. The results consist of the proportion of acceptable judgments for each sentence

NP_1	NP_2	C-command	Stimulus sentence	Proportion acceptable
Name	Pronoun	No	(1) **Joan's** father respects **her**.	.94
Pronoun	Name	No	(2) **Her** father respects **Joan**.	.33
Name	Name	No	(3) **Joan's** father respects **Joan**.	.62
Pronoun	Anaphor	No	(4) **Her** father respects **herself**.	.04
Name	Anaphor	No	(5) **Joan's** father respects **herself**.	.06
Name	Pronoun	Yes	(6) **Joan** respects **her**.	.06
Pronoun	Name	Yes	(7) **She** respects **Joan**.	.12
Name	Anaphor	Yes	(8) **Joan** respects **herself**.	.94

judgments of co-reference involving anaphors and syntactic positions in which anaphors should occur if there were to be co-reference. The stimulus sentences in this experiment directly test Principles A, B, and C, by varying whether the antecedent c-commands the co-referential constituent or not. Table 5 shows the sentences that were used to gather subjects' judgments of co-reference involving anaphors or the positions they should occupy for co-reference to be possible.

11. Method

11.1. Subjects

The subjects were the same 48 who participated in the previous experiment.

11.2. Stimuli

The stimuli consisted of the set of eight sentences shown in Table 5. This set includes inappropriate and appropriate uses of anaphors, as well as different configurations of names and pronouns.

11.3. Procedure

The experiment was conducted as the second part of Experiment 2. The stimuli appeared on the second page of the questionnaire. Subjects were asked not to return to the first page once they had started the second page. Otherwise, the procedure was the same as in the previous experiments.

12. Results

Table 5 shows the results of the second part of the experiment. There was a significant main effect of sentence, $F(7, 322) = 69.2$, $p < .001$. Consistent with

Principle A, when an anaphor has a name as an antecedent, co-reference is more acceptable when the antecedent has a c-commanding position (sentence 8) than a non-commanding antecedent (sentence 5), $F(1, 47) = 314.3$, $p < .001$. Consistent with Principle B, when a pronoun has a name as an antecedent, co-reference is less acceptable when the antecedent has a c-commanding position (sentence 6) than a non-commanding antecedent (sentence 1), $F(1, 47) = 314.3$, $p < .001$. C-command also had an effect on acceptability of co-reference in pronoun-name sequences, $F(1, 47) = 6.2$, $p < .025$, as shown by a comparison of sentences 2 and 7. This effect of c-command is smaller than that observed for anaphors (Principle A), $F(1, 47) = 45.8$, $p < .001$, or for pronouns (Principle B), $F(1, 47) = 50.7$, $p < .001$. A comparison of sentences 2 and 3 shows that names are favored over pronouns as antecedents, $F(1, 47) = 10.1$, $p < .005$.

13. Discussion

The results summarized in Table 5 indicate clearly that subjects' knowledge corresponds to that modeled in Principles A and B of the Binding Theory. If we compare sentences 5 and 8 (.04 and.94 acceptability respectively) we observe the effect of Principle A. Sentences 1 and 6 (.94 and.06 acceptability respectively) illustrate the effect of Principle B. These distinctions are large and of the same magnitude.[10]

This experiment reconfirms a finding of our two earlier experiments by showing that names and pronouns behave asymmetrically as antecedents. Comparing sentence 2 (.33 acceptability) with sentence 3 (.62 acceptability), we can clearly see that pronoun-name sequences give rise to sentences with less acceptability than name-name sequences. However, comparing sentence 2 and sentence 7, we can see that the absence of a c-command relation yields an increase in the acceptability of co-reference in pronoun-name sequences, an effect that is in the direction expected from Principle C of the Binding Theory and one we did not observe in Experiment 1. While this effect is statistically significant, it is smaller than would be expected based on Principle C.

This experiment shows that, in contrast to Principle C, Principles A and B provide an accurate account of naive subjects' judgments. The remaining experiments in this paper examine possible reasons for why Principle C is inconsistent with the judgments of naive subjects with regard to co-referential interpretation of names with preceding expressions.

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[10] These findings are relevant to a recent controversy over whether binding should be distinguished from co-reference more generally. Grimshaw and Rosen (1990) argue for the traditional account in which no distinction is made between the two. Grodzinsky and Reinhart (1993) argue, on the basis of language acquisition and aphasia studies, that Principle A is more robust than Principles B and C, and therefore is the only domain in which true binding of variables occurs. Our data show that both Principles A and B are more robust than Principle C, supporting an intermediate position between those offered by Grimshaw and Rosen (1990) and Grodzinsky and Reinhart (1993).

EXPERIMENT 4

With respect to Principle C, our results so far show the following pattern. For co-reference of two names, naive subjects show some acceptance of the dictates of Principle C of Binding Theory. They do so to a greater degree when the antecedent name is the subject of the sentence than when it is an object. This indicates that the height of the c-commanding NP within the syntactic structure of the sentence may be an important factor in the use of c-command. When it comes to co-reference of names and preceding pronouns, subjects only obey the dictates of Principle C in the case where preposing an adjunct phrase causes the pronoun not to c-command the name. In other cases subjects tend to reject co-referential interpretation of a name and a preceding pronoun even when the pronoun does not c-command the name (though an effect in the appropriate direction was observed in Experiment 2). This rejection occurs even for cases where the same subjects use the c-command relation in the case of co-reference of two names. These results lead to two tentative conclusions: First, co-referential interpretation of two names and co-referential interpretation of a pronoun and a name are not responsive to the same structural factors. Second, the ability to co-referentially interpret a name and a preceding pronoun depends on a suspension of full interpretation of the initial pronoun.

The current experiment seeks to provide further support for this pattern of results and further insight into why it occurs. It examines the acceptability of co-reference in a set of stimuli (see Appendix C) that vary c-command using two different NP manipulations (possessives and conjuncts) and two kinds of c-commanding antecedents (subject and object). Subjects are asked to rate the acceptability of co-reference in these sentences rather than simply indicating whether co-reference is acceptable or not. A rating scale is used because it may provide more sensitivity than a binary judgment to subtle aspects of syntactic structure. Finally, in this experiment we use two different sets of instructions on how to make the grammaticality judgments. The ''reflective'' instructions ask subjects to read the sentence once, repeat it to themselves, and then make a rating of the acceptability of co-reference. The ''immediate'' instructions asked subjects for their initial reaction after they have read through the sentence once. We hypothesize that the reflective instructions will lead to a strategy that involves more delayed interpretive commitments and more attention to syntactic structure. This may lead to greater effects of c-command on the acceptability of co-indexing names with preceding pronouns.

14. Method

14.1. Subjects

Ninety-four subjects from the same population as the previous experiments participated in the study. None of them had participated in the previous

experiments. The questionnaires with the "reflective" instructions were administered to two sections of the class with a total of 49 students. The questionnaires with the "immediate" instructions were administered to another two sections with a total of 45 students.

14.2. Stimuli

There were eight versions of each of the six referential configurations, as shown in Appendix C. These eight versions include two examples of each of the two types of c-commanding antecedents (subject and object) combined with each of the kinds of NP manipulations (possessives and conjuncts).

14.3. Procedure

The procedure was the same as in the previous experiments with the following exceptions. Subjects were asked to use the following scale to make their judgments:

1 = Completely Unacceptable
2 = Unacceptable
3 = Just Barely Unacceptable

4 = Just Barely Acceptable
5 = Acceptable
6 = Completely Acceptable

There were also two versions of the instructions that emphasized different approaches to making the grammaticality judgment. The reflective instructions said: "We would like you to make these ratings very carefully. Read through the sentence once, then say it to yourself mentally before giving the rating." The immediate instructions said: "We are interested in your immediate reaction to these sentences. Read through a sentence once and then judge it immediately without reflection." Otherwise, the procedure was the same as in the previous experiments.

15. Results

15.1. NP sequence and c-command

Table 6 shows the mean acceptability rating for each co-reference type, separately for each instruction condition and averaged overall. There was no significant main effect of c-command, $F(1, 93) < 1$. There was a significant main effect of sequence of type of referring expression, $F(2, 93) = 190.4$, $p < .001$, as well as a significant interaction of c-command and type of referring expression,

Table 6

Results for Experiment 4 averaged across stimuli. The table shows the proportion of acceptable sentences as a function of c-command relation and type of NP sequence, for the reflective instructions, the immediate instructions, and averaged across the two

	C-command	Reflective	Immediate	Average
Name–pronoun	No	4.48	4.45	4.47
Name–pronoun	Yes	5.39	5.24	5.32
Name–name	No	4.24	3.98	4.12
Name–name	Yes	3.53	3.48	3.50
Pronoun–name	No	2.58	2.84	2.70
Pronoun–name	Yes	2.14	2.78	2.44

$F(2, 93) = 92.8$, $p < .001$. Post hoc tests on c-command within each of the NP sequences were conducted. In the name-pronoun condition, significantly higher ratings were given to sentences with c-commanding antecedents as compared to those without, $t(93) = 10.1$, $p < .001$. In the name-name condition, significantly lower ratings were given to sentences with c-commanding antecedents, $t(93) = 9.1$, p < .001. In the Pronoun-Name condition, significantly lower ratings were also given to sentences with c-commanding antecedents, t(93) = 2.96, p < .05. There was significantly larger effect of c-command in the Name-Name condition than in the Pronoun-Name condition, t(93) = 3.9, $p < .005$.

15.2. Effect of instructions

The main effect of instructions was not significant, $F(1, 92) = 1.3$, $p > .25$. The interaction of type of referring expression and instructions was significant, $F(2, 184) = 3.8$, $p < .025$. The interaction of c-command and instructions fell just short of traditional levels of significance, $F(1, 92) = 3.42$, $p = .068$. When the interaction of instructions and c-command was examined for just the name-name and pronoun-name conditions, it was found that there was a significantly greater effect of c-command with the reflective instructions as compared to the immediate instructions, $t(92) = 2.7$, $p < .05$. In the name-name condition, there were significant effects of c-command both with reflective instructions, $t(48) = 6.93$, $p < .001$, and with immediate instructions, $t(44) = 6.09$, $p < .001$. In the pronoun-name condition, there was only a significant effect of c-command with reflective instructions, $t(48) = 4.86$, $p < .001$, not with immediate instructions, $t(44) = .24$, $p > .25$.

15.3. Types of sentences

Table 7 shows the co-reference ratings broken down by sentence type. (Appendix C shows the ratings for each of the individual stimulus sentences.) There was no significant main effect of whether the antecedent was in the subject NP, $F(1, 93) < 1$. There were significant interactions of the antecedent's subject status and c-command ($F(1, 93) = 38.4$, $p < .001$), NP sequence ($F(2, 186) =$

Table 7
The results of Experiment 4. The mean acceptability ratings are presented (averaged over the reflective and immediate conditions) broken down by sentence type and type of NP sequence. C-command was manipulated by the positioning of a possessive NP or a conjunctive NP, and antecedent expression could be located in the subject or in the object

	C-command	Possessive subject	Possessive object	Conjunct subject	Conjunct object
Name–pronoun	No	5.46	4.99	3.77	3.64
Name–pronoun	Yes	5.70	5.49	4.95	5.13
Name–name	No	4.22	4.14	4.07	4.05
Name–name	Yes	3.08	3.94	3.32	3.67
Pronoun–name	No	3.01	2.84	2.46	2.48
Pronoun–name	Yes	2.39	2.37	2.45	2.54

10.7, $p < .001$), and the three-way interaction of these factors ($F(2, 186) = 7.99$, $p < .001$). The pattern of these interactions can be summarized by saying that in the name-pronoun condition the effect of c-command was greater when the antecedent was not in the subject NP, but that for the name-name and pronoun-name conditions the effect of c-command was greater when the antecedent was in the subject NP. Post hoc contrasts on the name-name condition showed that c-command had a significant effect when antecedents were subjects ($t(93) = 10.4$, $p < .001$) and when they were objects ($t(93) = 3.4$, $p < .05$). For the pronoun-name condition, there was a significant effect of c-command when antecedents were subjects ($t(93) = 3.06$, $p < .05$) but only a marginal effect when they were objects ($t(93) = 2.05$, $p > .05$).

There was a significant effect of type of NP (possessive vs. conjunction), with possessives being rated more highly, $F(1, 93) = 109.5$, $p < .001$. There were significant interactions of NP type and c-command ($F(1, 93) = 42.1$, $p < .001$), NP sequence ($F(2, 186) = 48.5$, $p < .001$), and the three-way interaction of these factors ($F(2,186) = 12.2$, $p < .001$). The most striking factor contributing to this pattern of interactions was the very low average rating assigned to the name-pronoun condition with conjoined NPs when there was no c-command relation between the NPs—that is, when the subject NP was a conjunction and the subsequent pronoun was to be taken as co-referential with one of the names in the conjunction. Post hoc contrasts on the name-pronoun condition showed that c-command had a significant effect for possessives ($t(93) = 4.9$, $p < .005$) and for conjunctions ($t(93) = 9.9$, $p < .001$). For the name-name condition, there was a significant effect of c-command for possessives ($t(93) = 8.02$, $p < .001$) and for conjunctions ($t(93) = 6.03$, $p > .001$). For the pronoun-name condition, there was a significant effect of c-command for possessives ($t(93) = 3.94$, $p < .05$) but no significant effect for conjunctions ($t(93) = .37$, $p > .25$).[11]

16. Discussion

The results of the experiment are largely consistent with those of Experiment 1, but go beyond that experiment in providing information about the validity of Principle C of Binding theory in various syntactic constructions and about the role of psychological strategies in the process of judging grammatical acceptability. We address these in turn.

16.1. Principle C in different syntactic sequences

Breaking down the results into the different sentence types shows that the basic effects of c-command and NP sequence hold up across the sentence types, but are

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[11] Instructions only entered into one interaction with any of the sentence type factors, an interaction with subject status of the antecedent, $F(1, 92) = 5.5$, $p < .05$. Given the number of interactions tested, we do not attempt to interpret this unexpected result.

modulated by the syntactic role of antecedent (subject vs. object). This moderating effect operates in the opposite direction on NP sequences where c-command favors co-reference (name-pronoun) and where it disfavors co-reference (name-name and pronoun-name). The effect of c-command in favoring co-referential interpretation is greater when the antecedent is within an object than when it is within a subject. In contrast, the effect of c-command in disfavoring co-referential interpretation is less when the antecedent is an object than when it is a subject. Put another way, this pattern suggests a simple unifying principle for how co-reference and disjoint reference interact with syntactic structure. Pronouns are easily seen as co-referential with a prominent preceding name, while names are not easily seen as co-referential with a prominent preceding name. Here, prominence can initially be seen as inversely dependent on the number of branching nodes dominating an NP. This notion is similar to c-command in its reference to domination by branching nodes, but different in that it does not describe a relation between two NPs. On this analysis, c-commanding entities are more prominent than non-c-commanding entities. Also, subject antecedents are more prominent than object antecedents.

The notion that candidate entities for co-referential interpretation differ in prominence as a function of their linguistic characteristics is an integral part of centering theory and related approaches characterizing the coherence of local discourse segments (Gordon et al., 1993; Grosz et al., 1983, 1986, 1995; Sidner, 1983). In centering theory, these entities are characterized as belonging to an ordered set of forward-looking centers consisting of the semantic objects that are part of the model of the discourse. The ordering of the set affects the availability of these objects for subsequent reference. Experimental research on self-paced reading by Gordon et al. (1993) has shown that status as subject and being the first NP in a sentence both contribute to prominence in the set of forward-looking centers as measured by the ease of understanding different kinds of referring expressions in the subsequent sentence. Two kinds of effects are observed: (1) Using a name to refer to the most prominent entity in the previous sentence causes an elevation in reading times (Gordon et al., 1993; Gordon and Chan, 1995); (2) Using a syntactically ambiguous pronoun to refer to the most prominent entity in an utterance causes no difficulty in reading, while using a syntactically ambiguous pronoun to refer to a less prominent entity causes a disruption of reading due to garden-pathing (Gordon and Scearce, 1995). We believe that the same factors account for the pattern of intra-sentential co-reference, examined in the present experiments, as account for the inter-sentential co-reference effects just described. We will develop this notion below in the General Discussion.

The breakdown of results according to sentence type shows an additional very substantial effect for the name-pronoun condition with NPs containing conjunctions. Co-referential interpretation receives an average acceptability rating of just 3.71 when there is no c-command relation between the NPs, while it receives a rating of 5.04 when there is a c-command relation. From the perspective of classical binding theory, this result is quite surprising. However, we believe that the notions of prominence discussed above provide a natural way of accounting for it. When there is no c-command relation, the first NP in the sentence is a

conjunction and the subsequent pronominal reference must be seen as co-referring with one of the names in the conjunction. We hypothesize that the named entity is less prominent than the complex semantic entity (or group) that is created through the conjunction. Accordingly, a singular pronoun must be seen as referring to an entity that is not the most prominent one that is currently available for co-reference.

16.2. Effects of instructional set on responsiveness to c-command

The effect of c-command was significantly greater with reflective rather than immediate instructions for both name-name and pronoun-name sequences. Intuitive judgments of grammaticality are often presented as pure windows on knowledge, abstracted from issues of psychological performance. The current findings do not support this idealization, though one might still want to argue that intuitions provide the best insight into grammatical knowledge. Previous research by Carroll et al. (1981) has shown that subjects' judgments of the similarity of sentences can be influenced by their attitudinal set, which can be induced to be more objective by looking at oneself in a mirror while performing a judgment task. It is not clear whether the Carroll et al. (1981) mirror manipulation and our instructional manipulations had similar effects on how subjects performed their linguistic judgments. It is clear that neither their results nor ours are consistent with Fodor's (Fodor, 1983) assertion that human responses to syntactic structure are reflexive. Instead, important aspects of these responses can be influenced by reflection, be it from a mirror or at an experimenter's behest.

A significant effect of c-command for pronoun-name sequences was found only with reflective instructions, not with immediate instructions. This is consistent with the idea that the immediate instructions induced a set similar to that in Experiment 1, where an effect of c-command on pronoun-name sequences was also not observed. The reflective instructions caused subjects to handle pronoun-name sequences in a manner more similar to that observed in Experiment 2, where co-reference between a preceding pronoun and a name was deemed highly acceptable when the pronoun was in a preposed adjunct phrase. We hypothesized that this acceptability derived from a suspension of a full interpretation of the initial pronoun until after the preposed phrase was fit into the syntactic structure of the sentence. Our reflective instructions were meant to encourage something like this sort of suspension of interpretation by asking subjects to read through the test sentences twice. Those instructions had the expected effect on subjects' judgments of the acceptability of co-referential pronoun-name sequences, though the magnitude of this effect did not approach that of preposing the adjunct phrases. This pattern provides tentative support for the notion that the dynamics of interpreting noun phrases plays an important role in patterns of acceptable co-reference.

Linguists typically talk about c-command as a syntactic relation computed on a representation. An alternative hypothesis might take c-command to be a relation that emerges from the way syntactic structure is built or parsed. That is to say, c-command can be viewed as a fact of the representation that is processed or as a

fact about how processing of a representation proceeds. Berwick and Weinberg (1984) first put forth the general spirit of this second view, although it was offered without empirical motivation. In the General Discussion of this paper, we will present a model of linguistic co-reference in which certain factors, such as syntactic position and type of referring expression, are potential triggers to interpretation and where the dynamics of interpretation are critical to the acceptability of co-reference. The dynamic component of this model will require testing through methods that more directly examine the timecourse of sentence processing, but we believe that our assumptions about these components are plausible and that a first step in evaluating the model is its accuracy in accounting for patterns of acceptable co-reference.

The finding that reflective instructions cause c-command to have a small effect on the acceptability of co-reference in pronoun-name sequences reduces the divergence between the judgments of naive subjects and those judgments that have provided the basis for the Binding Theory. However, the small size of the effect (less than one unit on a 6-point scale) and the low acceptability (below the midpoint) of the non-c-commanding pronoun-name sequences combine to indicate that a substantial divergence remains. The next experiment addresses another possible basis of this divergence.

EXPERIMENT 5

One of the skills that linguistic training develops is facility at imagining contexts in which a sentence might be appropriate. This skill is useful in distinguishing sentences that are merely inappropriate in some contexts from sentences that are ungrammatical in any context. In the case of co-reference in pronoun-name sequences, this might involve imagining a context in which the initial pronoun could be interpreted as referring to an entity that has been mentioned already in discourse. Such an interpretation would remedy these sentences of the interpretive anomaly that results from having an expression with little independent ability to refer precede an expression that does have this ability when the two are supposed to be co-referential. The current experiment addresses this possibility by asking subjects for judgments of the acceptability of co-reference in sentences that are embedded in a discourse context that mentions the name that participates in the subsequent co-reference. As Table 8 shows, this is done using the sentence to be judged as an answer to a question. The effect of the question context was studied on four types of referential sequences (pronoun-pronoun, name-pronoun, name-name and pronoun-name) in cases where the intra-sentential antecedent c-commanded the subsequent referring expression and where it did not.

The present use of a discourse context raises questions of inter-sentential co-reference of the sort that are addressed by research on centering theory (Grosz et al., 1983, 1986, 1995; Gordon et al., 1993). That research has shown that a short discourse is read more quickly when a pronoun rather than a name is used to realize an entity in a prominent syntactic position of an utterance and when that entity was in a syntactically prominent position in the immediately preceding

Table 8

Sample stimuli used in Experiment 5

C-command	NP sequence	Question	Answer
No	Pronoun–pronoun	Who visited Lisa at college?	**Her** brother visited **her** at college.
Yes	Pronoun–pronoun	Who did Lisa visit at college?	**She** visited **her** brother at college.
No	Name–pronoun	Who visited Lisa at college?	**Lisa's** brother visited **her** at college.
Yes	Name–pronoun	Who did Lisa visit at college?	**Lisa** visited **her** brother at college.
No	Name–name	Who visited Lisa at college?	**Lisa's** brother visited **Lisa** at college.
Yes	Name–name	Who did Lisa visit at college?	**Lisa** visited **Lisa's** brother at college.
No	Pronoun–name	Who visited Lisa at college?	**Her** brother visited **Lisa** at college.
Yes	Pronoun–name	Who did Lisa visit at college?	**She** visited **Lisa's** brother at college.

utterance. Extrapolation from those results to the present study invites the prediction that the presence of a context question would cause a preference for the use of pronouns as compared to names. However, it is important to note that centering theory applies within the boundaries of discourse segments and does not apply across those boundaries. While the criteria for determining the boundaries of discourse segments are not yet clear (Gordon, 1993; Grosz and Sidner, 1986), it is plausible that a question and an answer would be attributed to different voices and therefore potentially to different discourse segments.

17. Method

17.1. Subjects

Eighty-three subjects from the same population as the previous experiments participated in the study. None of them had participated in the previous experiments. The surveys that included the context question were administered to two sections of the class with a total of 36 students. The questionnaires without the context questions were administered to another two sections with a total of 47 students.

17.2. Stimuli

There were four versions of each of the eight referential configurations, as illustrated in Table 8. These four versions consisted of two examples of each of the two types of c-commanding antecedents (subject and object). C-command relations were manipulated by the positioning of a possessive noun phrase. In the question condition, the sentence to be judged was preceded on the same line of the survey by a question that mentioned the name of the entity that was referred to by the judged expressions.

17.3. Procedure

The question/no-question factor was manipulated between subjects. In both conditions, subjects were asked to use the rating scale for co-referential interpretation that was described in the previous experiment and they were given the reflective instructions. In the question condition, subjects were asked to read both the question and the answer and then to judge the acceptability of a co-referential interpretation of the bold-faced expressions in the answer. The instructions in the no-question condition were the same as in the previous experiment.

18. Results

Table 9 shows the mean acceptability rating for each type of co-referential sequence. The experiment was analyzed as a five-factor ANOVA with question

Table 9
The results of Experiment 5

	No c-command		C-command	
	NP_1 (name)	NP_1 (pronoun)	NP_1 (name)	NP_1 (pronoun)
No question				
NP_2 (name)	4.09	3.12	3.38	2.38
NP_2 (pronoun)	5.29	5.01	5.77	5.37
Question				
NP_2 (name)	3.91	3.36	3.18	2.63
NP_2 (pronoun)	5.25	5.19	5.43	5.65

being a between-subject factor and form of NP_1, form of NP_2, c-command between NP_1 and NP_2, and antecedent in the subject or object being with-subject factors. We will first present analyses involving the question factor, and then present analyses involving the kinds of factors studied in the preceding experiment.

18.1. Context question

There was no significant main effect of the context question, $F(1, 81) < 1$. There was a significant interaction of question and form of NP_1; the presence of a question caused higher ratings to be given to sentences in which NP_1 was a pronoun (4.17 vs. 3.97) and lower ratings to be given when NP_1 was a name (4.60 vs. 4.75), $F(1, 81) = 6.3$, $p < .025$. The presence of a context question entered into no other significant interactions. In particular, it did not modulate the effect of c-command on the acceptability of pronoun-name sequences; a non-c-commanding relation in pronoun-name sequences increased acceptability ratings by .74 when there was no context question and by .73 when there was a context question, $F(1, 81) < 1$.

18.2. NP sequences, c-command and location of the antecedent

The overall acceptability of co-reference differed in the four types of NP sequences. From highest to lowest, it was: name-pronoun (5.48), pronoun-pronoun (5.25), name-name (3.65), pronoun-name (2.86); the reliability of this pattern is shown by the highly significant linear effect of sequence type arranged in this order, $F(1, 82) = 481.5$, $p < .001$. A c-command relation increased the acceptability of co-reference in name-pronoun and pronoun-pronoun sequences ($F(1, 82) = 58.0$, $p < .001$ and $F(1, 82) = 19.6$, $p < .001$ respectively) and decreased the acceptability of co-reference in name-name and pronoun-name sequences (($F(1, 82) = 63.6$, $p < .001$ and $F(1, 82) = 41.9$, $p < .001$ respectively).

The location of the antecedent (within subject or within object) moderated the effect of c-command in two cases: For name-pronoun sequences, having the antecedent in the subject yielded a smaller positive effect of c-command (a difference of .13 between sequences with c-command and without) on acceptabili-

ty of co-reference as compared to having the antecedent in the object (a difference of .70), $F(1, 82) = 12.2$, $p < .005$. For name-name sequences, having the antecedent in the subject increased the negative effect of c-command (a difference of -1.11 between sequences with c-command and without) on acceptability of co-reference as compared to having the antecedent in the object (-.32), $F(1, 82) = 31.8$, $p < .001$. Location of antecedent did not moderate the effect of c-command on acceptability of co-reference in pronoun-name sequences ($F(1, 82) = 1.8$, $p > .15$) or pronoun-pronoun sequences ($F(1, 82) < 1$).

19. Discussion

The results showed that the presence of a context question did not significantly increase the effect of c-command on the acceptability of co-reference in pronoun-name sequences. Co-referential interpretation in non-c-commanding pronoun-name sequences remained low even when the initial pronoun could be interpreted as referring to the named entity mentioned in the context question. This suggests that the intuitive acceptability of co-reference in non-c-commanding pronoun-name sequences, which is observed in the judgments of trained linguists, does not arise from the ability to interpret the pronoun as referring to an imagined referent.[12]

While the presence of the question did not facilitate acceptance of co-reference in pronoun-name sequences, it did produce a small but significant effect on the co-reference judgments on the subsequent sentences. Acceptability of sequences beginning with pronouns was increased by the presence of a context question, while acceptability of sequences beginning with names was decreased. As discussed above, research on centering theory (Grosz et al., 1983, 1986, 1995; Gordon et al., 1993) has identified circumstances in which inter-sentential reference is processed more efficiently when the second referential expression is a pronoun rather than a name. The present preference for initial pronouns rather than names is consistent with those findings of centering theory. The small magnitude of the effect could derive from either of two sources. First, subjects were asked to judge the acceptability of co-reference within the second sentence, not between the second and first sentences. Therefore, the method may not have revealed the true magnitude of the effect. Second, the question and answer may be perceived as falling into separate discourse segments. According to centering theory, pronominal reference is only a basis for discourse coherence within discourse segments; separate discourse segments are related by the intentional structure of a discourse (Grosz and Sidner, 1986).

With respect to the acceptability of co-reference in pronoun-name sequences, we are again left with a divergence between the judgments of naive subjects and the self reports of trained linguists. The next experiment continues our attempts to

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[12] The results of the experiment having to do with the interaction of c-command with different types of noun-phrase sequences and with the syntactic role of the antecedent are consistent with those we have observed previously.

understand this divergence. It again examines the effect of context, this time by manipulating the judgment context of the surrounding sentences rather than the discourse context of the sentence to be judged.

EXPERIMENT 6

Experimental psychologists have long believed that judgments are relative; even if subjects are not directly asked to compare stimuli, their judgments of individual stimuli will be made relative to the set of stimuli being judged (Helson, 1947; Parducci, 1956; Parducci, 1984). Parducci's range-frequency theory characterizes implicit relative judgment as a balance between two tendencies: The first is to divide the subjective range of the stimuli along the to-be-judged dimension into equal subranges, while the second is to use each response category with equal frequency. Both these tendencies have the effect of compressing the judged difference between stimuli that are similar when other very dissimilar stimuli must be judged in the task. This is particularly true when the number of response categories is small relative to the range of differences in the stimuli. This analysis suggests that our experiments so far may not have revealed strong effects of c-command on the grammatical acceptability of co-reference in pronoun-name sequences because the difference is compressed by the presence of types of sequences in which co-reference is very acceptable.

The current experiment examines whether having a judgment context that includes sequences for which co-reference is highly acceptable influences the magnitude of the difference in acceptability of co-reference in pronoun-name sequences with and without c-command. The judgment context is manipulated between subjects in the following way. In one condition, subjects only judge the acceptability of co-reference in pronoun-name sequences; in half the sentences the pronoun c-commands the name and in half it does not. In the second condition, these same sentences are randomly intermixed among matched sentences that contain name-pronoun sequences. In the final condition, pronoun-pronoun sequences are used in place of name-pronoun sequences. We will refer to these three conditions as *no context*, *name-pronoun context*, and *pronoun-pronoun context*.

20. Method

20.1. Subjects

Eighty-nine subjects, from the same population as before, were tested in the study. Twenty-nine were tested in the no-context condition, 33 in the name-pronoun context condition, and 27 in the pronoun-pronoun context condition. None of the subjects had participated in the previous experiments.

20.2. Stimuli

The stimuli were the possessive constructions used in Experiment 4 (see Appendix C). As such they differed in whether the antecedent c-commanded the second referring expression and in terms of whether the antecedent was within the subject or an object. The same set of pronoun-name sequences was presented in all context conditions. For the name-pronoun context, an additional set of sentences was included that was made by reversing the location of the pronoun and name. For the pronoun-pronoun condition, a set of pronoun-pronoun sentences was added to the pronoun-name sentences; these were made by substituting pronouns for names. Six different randomizations of the sentences were used in each context condition.

20.3. Procedure

Subjects were given the categorical acceptability instructions used in Experiments 1–3.

21. Results

Table 10 shows the proportion of acceptable judgments for pronoun-name sequences in each of the three context conditions and as a function of the syntactic status of the antecedent; it also shows the proportion acceptable for the context sentences. Overall, co-reference was deemed more acceptable when the antecedent was not in a c-commanding position than when it was, $F(1, 86) = 81.8$, $p < .001$. Further, there was a significant interaction of c-command and context. The difference in acceptability of co-reference due to c-command was .54 in the no-context condition, while it was .21 in the average of the other two context conditions, $F(1, 87) = 20.0$, $p < .001$. (There was no significant difference in the effect of c-command between the name-pronoun and pronoun-pronoun context conditions, $F(1, 58) < 1$. There was no significant effect of location of the antecedent (subject vs. object) and all interactions involving antecedent fell short of significance.

Table 10
Results of Experiment 6. The proportion of acceptable co-reference in each experimental condition

Context type		Acceptability of pronoun–name co-reference			
		Antecedent in subject		Antecedent in object	
	Acceptability of context sentences	No c-com	C-com	No c-com	C-com
None		.638	.052	.603	.103
Name–pronoun	.958	.333	.076	.212	.061
Pronoun–pronoun	.917	.389	.148	.278	.093

22. Discussion

The results of the experiment show that the mix of sentences to be judged has a strong effect on whether co-reference is deemed acceptable in pronoun-name sequences where the antecedent is not in a c-commanding position. When subjects are asked to judge only pronoun-name sequences, then co-reference is accepted 62% of the time when the antecedent is not c-commanding. When the sentences containing pronoun-name sequences are mixed in with matched sentences that contain sequences with very high rates of acceptability, then the acceptability of the non-commanding pronoun-name sequences drops substantially, down to 27% with the addition of name-pronoun sequences and to 33% with the addition of pronoun-pronoun sequences. The acceptability of co-reference in pronoun-name sequences with a c-commanding antecedent is influenced less by the mix of sentences; it ranges from 8% with no additional sentences to 7% with name-pronoun sequences to 12% with pronoun-pronoun sequences.

These results show that naive subjects are sensitive to the effect of c-command on pronoun-name co-reference under the following circumstance: when the set of sentences to be judged includes no sequences in which co-reference is highly acceptable, then subjects are more accepting of co-reference in non-commanding pronoun-name sequences. This result is consistent with the tenets of adaptation-level theory (Helson, 1947) and of range-frequency theory (Parducci, 1956, 1984) and supports two important conclusions. First, c-command has a real effect on the grammatical acceptability of co-referential interpretation of pronoun-name sequences, an effect that was partially masked in our previous experiments due to the presence of other types of NP sequences. Second, this effect should be characterized as comparatively weak because of its susceptibility to being covered up by the presence of other types of NP sequences. In contrast, Experiment 2 showed that co-reference in pronoun-name sequences was highly acceptable (88%) when the pronoun occurred in a fronted adjunct phrase. This high acceptability was observed in an experiment in which subjects also made judgments on sentences containing name-pronoun sequences where co-referential interpretation is highly acceptable. Clearly, a pronoun in a fronted adjunct phrase is far more acceptable as an antecedent for a subsequent name than is a pronoun that is embedded in a constituent as a possessive noun phrase. It was the desire to provide a unified explanation for both the former and latter cases that motivated the development of the c-command construct as a general explanation of disjoint reference (Reinhart, 1976, 1981; Chomsky, 1981).

We may speculate that trained linguists are highly accepting of co-reference in non-c-commanding pronoun-name sequences because of the kinds of grammaticality judgments their profession invites them to consider. The most theoretically interesting questions of grammaticality often fall on the border between what is acceptable and what is not.[13] This focus on borderline cases may cause

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[13] See, for example, Chomsky's (Chomsky, 1982) discussion of "parasitic gaps".

linguists to be more grammatically accepting than they would be if they made their judgments in the context of highly acceptable sentences. Further, we have the impression that linguists interested in Principle C of the Binding Theory tend to focus their judgments on pronoun-name sequences. This tendency can be seen in presentations of the basis for Principle C (see footnote 6). If this supposition is correct, then linguists make their judgments of the grammaticality of co-referential interpretation of such sequences under broadly the same circumstances as the subjects in the current experiment who were only given pronoun-name sequences to judge. The resulting pattern of acceptability is limited to a class of judgments made in situations that do not include sentences containing NP sequences where co-reference is highly acceptable.

GENERAL DISCUSSION

Our exploration of the patterns of co-reference acceptable to competent speakers of English who are naive to linguistic theory has yielded some expected, as well as some surprising, results. Here, we attempt to sketch a unified explanation of the following findings:

1. The acceptability of co-reference between two NPs depends on their type. It is highest for name-pronoun sequences, intermediate for name-name sequences, and lowest for pronoun-name sequences, as shown by Experiments 1 and 4.
2. A c-command relationship between the NPs reduces the acceptability of co-reference in name-name sequences; it enhances acceptability in name-pronoun sequences and it generally has little effect on pronoun-name sequences. The effect of c-command on disjoint reference is greater when the antecedent is within the subject of the main clause, while the effect of c-command on co-reference is greater when the antecedent is not within the subject. Co-reference between a name and a preceding pronoun is widely accepted when the pronoun is in a preposed adjunct phrase, as shown by Experiment 2.
3. The effect of c-command on disjoint reference increases when subjects are asked for reflective, rather than immediate, judgments. It is also influenced by the mix of sentences that subjects are asked to judge. Experiment 6 showed that in the absence of highly acceptable sentences, judgments of pronoun-name sequences became more favorable towards structures in which the pronoun does not c-command the name.
4. Subjects' judgments concerning co-reference involving anaphors and pronominals are consistent with the dictates of Principles A and B, as shown by Experiment 3.
5. Preceding a sentence containing a co-reference relation with a context question causes an increase in the acceptability of sentences that begin with pronouns as compared to those that begin with names. However, such context questions do not specifically increase the acceptability of pronoun-name sequences lacking c-command.

Our explanation considers patterns of acceptable co-reference as deriving from the way in which syntactic representations are mapped onto discourse representations. As such, it characterizes grammatical intuition as emerging from the processing of language, not from linguistic competence. The explanation can be expressed in the formalism created by Kamp and Reyle (1993), which seeks to apply model theoretic semantics to phenomena in natural language, particularly the semantics of discourse.[14] Our use of Kamp and Reyle's framework requires that we develop specific theoretical accounts of the processing of syntactic representations that go beyond those in Kamp and Reyle, who focus their work on issues in logic. To do so, we draw on theoretical work on syntax and on the structure of locally coherent discourse. We present a formal account of this explanation in Gordon and Hendrick (1996). Here we offer a summary of that explanation.

Models based on the Kamp and Reyle formalism use *Construction Rules* to map syntactic representations onto *Discourse Representation Structures*. Each construction rule is composed of a *triggering condition* that delineates the linguistic input that causes the rule to apply, and specific instructions for replacing part of the linguistic representation with information in the Discourse Representation Structure. The material added to a Discourse Representation Structure by a Construction Rule is termed a *condition set*. What we take to be important in this formalism is that syntactic structures trigger the building of a part of a discourse representation structure in a dynamic fashion. Entities are introduced into the universe of the discourse by the dynamic rules that construct these representations. These entities are termed *discourse referents*.

Our model includes three construction rules to handle reference and co-reference. The construction rule for names is triggered by the occurrence of a name in the syntactic representation of the input sentence. It then posits a new discourse entity in the discourse model upon which the name is predicated. The construction rule for pronouns is triggered by a pronoun; it then attempts to find a *suitable antecedent* in the discourse model. Failing that, it posits a new discourse entity. The final construction rule (for equivalence) is triggered by the presence of the same name predicated on two different discourse entities.[15] It adds a condition set to the discourse representation equating the two entities. These three rules provide a straightforward account of our results concerning the acceptability of co-reference in the three types of NP sequences. Name-pronoun sequences trigger successive application of the construction rule for names and then for pronouns. The rule for names posits a discourse entity upon which a name is predicated; this subsequently provides a suitable antecedent when the construction rule for pronouns is triggered, yielding co-referential interpretation of the name and

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[14] A similar explanation could be framed in the system of Heim (1983).

[15] Our current presentation of the construction rule for equivalence is limited to cases where exactly the same name is predicated on two different entities. A more complete presentation of this rule would handle cases where names were not identical but could be known to refer to the same person. It would also handle cases where the identity between entities could be established based on semantic grounds.

pronoun. Name-name sequences trigger two applications of the construction rule for names, resulting in the same name predicated on two different discourse entities. This situation triggers the construction rule for equivalence, which equates the two discourse entities. Compared to name-pronoun sequences, establishing co-reference in name-name sequences requires an additional construction rule (equivalence) and results in a more complex discourse representation. This is in accord with our subjects' judgments of co-reference. Pronoun-name sequences first trigger application of the construction rule for pronouns. As it can find no suitable antecedent, it posits a new entity in the discourse model. Subsequently, the construction rule for names is triggered, resulting in the positing of an additional entity. However, the equivalence rule is not triggered at this point because the predication of the entity created by the pronoun rule has no identifying information. This accounts for the low acceptability of co-reference in pronoun-name sequences. The three construction rules can thus be seen as providing an account of finding 1, from the list above, concerning the relative acceptability of co-reference in the different kinds of sequences.

Accounting for finding 2, concerning the effects of c-command on co-reference, requires that we incorporate notions of linguistic prominence into the construction rules that we have sketched so far. In our formulation, linguistic prominence is inversely related to depth of embeddedness.[16] Other things being equal, this means that c-commanding antecedents will tend to have greater prominence, as will constituents of subjects relative to comparable constituents of objects. Prominence affects the construction of discourse representations in two ways: (1) It influences the order of processing triggers, with more prominent syntactic representations leading to earlier processing of triggers than less prominent representations; (2) It contributes to an ordering of the entities referred to in the discourse representation, and this ordering influences the efficiency with which the construction rules for establishing co-reference operate. (This second effect of prominence is equivalent to the notion in centering theory that the representation of an utterance in coherent discourse includes an ordered set of forward-looking centers.) Below, we discuss how prominence of this sort gives rise to syntactic effects in each of the types of NP sequence.

Co-reference in name-pronoun sequences occurs due to the construction rule for pronouns, which searches for a suitable antecedent among the discourse referents already present in the discourse representation. As research on centering theory has shown (Grosz et al., 1983, 1986, 1995; Gordon et al., 1993) such searches can be considered as proceeding through the available discourse entities in order of prominence. Because a c-commanding position promotes prominence, co-referential interpretations are arrived at more easily when the antecedent has such a position. Further, we expect this advantage to increase when the search for an antecedent must proceed very far down a long list of candidate discourse referents.

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[16] A similar idea was developed by Wasow (1979).

This explains why the effect of c-command on name-pronoun sequences is greater for antecedents within objects than for antecedents within subjects.

Co-reference in name-name sequences occurs due to the construction rule for names, which is triggered by the presence of the same identifying information predicated on two entities. However, before this rule is triggered the discourse model passes through a state where the same name is predicated on two distinct discourse entities. This state produces a sense of semantic incoherence as the entities increase in prominence because the predications involving the most prominent entities in the discourse are at its semantic core.[17] This semantic incoherence causes the sense of disjoint reference. Further, we expect this effect to increase when the c-commanding entity is within the subject of the sentence as compared to being within the object, since this increases its prominence.

Co-reference in pronoun-name sequences is highly acceptable when it is created by preposing adjuncts. This is because the preposed expression begins with a word (in our examples a preposition or the logical connective "if") that indicates that the preposed phrase does not build directly on the discourse representation begun by the previous utterance, but instead begins a new discourse representation. This occurs because the semantic interpretation of the preposed phrase is dependent on the interpretation of the subsequent matrix clause. We suggest that under these conditions, pronouns have a provisional referent assigned to them until the matrix clause is interpreted. At that point, the provisional referent can be equated to a previously existing or newly introduced discourse referent. This account is supported by parallels between intra-sentential and inter-sentential co-reference (Gordon et al., 1993; Gordon and Hendrick, 1996). This process of provisional interpretation is naturally available in phrases that are clearly preposed and whose semantic interpretation is consequently dependent on subsequent linguistic input. Under conditions of high task demands, this process may be generalized to cases where it does not naturally occur but where the pronoun is in non-argument position. This accounts for relatively high acceptability of co-reference in pronoun-name sequences without c-command, when subjects are not asked to judge any sentences in which co-reference is easily obtained.

Finding 3 is that c-command has a greater effect on disjoint reference when subjects are given reflective, rather than immediate, instructions. As we alluded to above, we see this effect as related to how immediately subjects attempt to interpret the linguistic input they are asked to judge. Reflective instructions lead to slower triggering of construction rules, which has the effect of diminishing left-to-right effects and of potentially allowing NPs on the right to be interpreted prior to ones on the left if they have high syntactic prominence. In this way, the reflective instructions lead to an increased effect of c-command on disjoint reference in pronoun-name sequences. Reflective instructions also increase the

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[17] This analysis is related to the notion of the "backward-looking center" developed by Grosz et al. (1983), 1986).

effect of c-command on disjoint reference in name-name sequences, though the influence of instructions is less than for pronoun-name sequences. This effect derives from delay in application of the construction rule for equivalence yielding a greater sense of semantic incoherence.

Finding 4 shows that subjects make very uniform judgments about the complementary distribution of reflexives and pronominals, as indicated by Principles A and B of binding theory. The essence of these principles can be incorporated into appropriate construction rules on how these forms are mapped onto discourse representations. In addition, the result shows that naive subjects have very strong intuitions about syntactic structure in clear cases, and that therefore their judgments should be taken seriously.

Finding 5 shows that prior mention of an entity causes an increase in the acceptability of referring to that entity with a pronoun in a subsequent sentence. This finding provides empirical support to our unified theoretical treatment of inter-sentential and intra-sentential co-reference.

23. Conclusion

The results reported in this paper show that judgments of acceptable co-reference in naive subjects systematically reflect important aspects of language structure. These judgments are consistent with some of the empirical claims of contemporary syntactic theory, particularly regarding the acceptability of co-reference involving anaphors and some pronominals. They are not consistent with claims concerning co-reference of names and some other pronominals. This pattern suggests a reformulation of the theory of co-reference that distinguishes the grammatical core responsible for the distribution of anaphors and a second set of operations that interpret names and pronouns. We account for patterns of acceptable co-reference between names and pronouns by analyzing how syntactic structures are mapped onto discourse representation structures. Syntactic structure plays a critical role in co-reference at this level by influencing the order in which entities are introduced into the representation of a discourse and by influencing the accessibility of entities within that representation. These representations also contribute directly to the psychological perception of coherence in extended segments of discourse. In this sense, syntactic structure can be seen as contributing to the organization of a larger discourse model that embodies the meaning of a linguistic communication.

Acknowledgments

Appendix A

Stimuli and results for individual sentences in Experiment 1

Sentence type	Stimulus sentence	Mean acceptability
Antecedent in subject	**John's** roommates met **him** at the restaurant.	1.00
	John met **his** roommates at the restaurant.	.98
	John's roommates met **John** at the restaurant.	.33
	John met **John's** roommates at the restaurant.	.12
	His roommates met **John** at the restaurant.	.29
	He met **John's** roommates at the restaurant.	.22
	Lisa's brother visited **her** at college.	.96
	Lisa visited **her** brother at college.	1.00
	Lisa's brother visited **Lisa** at college.	.47
	Lisa visited **Lisa's** brother at college.	.14
	Her brother visited **Lisa** at college.	.29
	She visited **Lisa's** brother.	.35
	The person **Susan** invited sat with **her** at the concert.	.98
	Susan sat with the person **she** invited at the concert.	1.00
	The person **Susan** invited sat with **Susan** at the concert.	.33
	Susan sat with the person **Susan** invited at the concert.	.25
	The person **she** invited sat with **Susan** at the concert.	.27
	She sat with the person **Susan** invited at the concert.	.18
Antecedent not in subject	Mary asked **Michael's** parents about **him**.	.98
	Mary asked **Michael** about **his** parents.	.96
	Mary asked **Michael's** parents about **Michael**.	.44
	Mary asked **Michael** about **Michael's** parents.	.33
	Mary asked **his** parents about **Michael**.	.22
	Mary asked **him** about **Michael's** parents.	.18
	Jane introduced **Bill's** teacher to **him**.	.90
	Jane introduced **Bill** to **his** teacher.	1.00
	Jane introduced **Bill's** teacher to **Bill**.	.33
	Jane introduced **Bill** to **Bill's** teacher.	.27
	Jane introduced **his** teacher to **Bill**.	.17
	Jane introduced **him** to **Bill's** teacher.	.20

Jill told the people **Sam** trusts all about **him**.	.75
Jill told **Sam** all about the people **he** trusts.	.84
Jill told the people **Sam** trusts all about **Sam**.	.35
Jill told **Sam** all about the people **Sam** trusts.	.33
Jill told the people **he** trusts all about **Sam**.	.16
Jill told **him** all about the people **Sam** trusts.	.18

Appendix B

Individual stimuli and results for Experiment 2

Sentence Type	Stimulus sentence	Mean acceptability
Clausal adjunct	Before **Susan** began to sing, **she** stood up.	.90
	Susan stood up before **she** began to sing.	.98
	Before **Susan** began to sing, **Susan** stood up.	.42
	Susan stood up before **Susan** began to sing.	.25
	Before **she** began to sing, **Susan** stood up.	.75
	She stood up before **Susan** began to sing.	.06
	If **Bill** does well on the exam, **he** will pass the course.	.98
	Bill will pass the course if **he** does well on the exam.	1.00
	If **Bill** does well on the exam, **Bill** will pass the course.	.54
	Bill will pass the course if **Bill** does well on the exam.	.38
	If **he** does well on the exam, **Bill** will pass the course.	.85
	He will pass the course if **Bill** does well on the exam.	.02
Prepositional phrase adjunct	For **Mary's** birthday, **she** got a new car.	.90
	Mary got a new car for **her** birthday.	1.00
	For **Mary's** birthday, **Mary** got a new car.	.56
	Mary got a new car for **Mary's** birthday.	.29
	For **her** birthday, **Mary** got a new car.	.98
	She got a new car for **Mary's** birthday.	.02
	In **Sam's** kitchen **he** keeps fresh herbs.	.83
	Sam keeps fresh herbs in **his** kitchen.	.98
	In **Sam's** kitchen **Sam** keeps fresh herbs.	.44
	Sam keeps fresh herbs in **Sam's** kitchen.	.31
	In **his** kitchen **Sam** keeps fresh herbs.	.94
	He keeps fresh herbs in **Sam's** kitchen.	.04

Appendix C

Individual stimuli and results for Experiment 4

	Sentence	Reflect.	Immed.	Avg.
Possessives				
Antecedent within subject	**Lisa's** brother visited **her** at college.	5.47	5.67	5.56
	Lisa visited **her** brother at college.	5.76	5.80	5.78
	Lisa's brother visited **Lisa** at college.	4.18	4.20	4.19
	Lisa visited **Lisa's** brother at college.	3.24	3.04	3.15
	Her brother visited **Lisa** at college.	2.98	3.18	3.07
	She visited **Lisa's** brother at college.	2.08	2.84	2.45
	John's roommates met **him** at the restaurant.	5.47	5.33	5.40
	John met **his** roommates at the restaurant.	5.61	5.64	5.63
	John's roommates met **John** at the restaurant.	4.39	4.13	4.27
	John met **John's** roommates at the restaurant.	2.92	3.09	3.00
	His roommates met **John** at the restaurant.	2.96	3.04	3.00
	He met **John's** roommates at the restaurant.	2.04	2.91	2.46
Antecedent within object	Mary asked **Michael's** parents about **him**.	5.16	5.07	5.12
	Mary asked **Michael** about **his** parents.	5.49	5.62	5.55
	Mary asked **Michael's** parents about **Michael**.	4.61	4.13	4.38
	Mary asked **Michael** about **Michael's** parents.	3.82	3.91	3.86
	Mary asked **his** parents about **Michael**.	2.88	3.18	3.02
	Mary asked **him** about **Michael's** parents.	2.22	2.80	2.50
	Jane introduced **Bill's** new teacher to **him**.	4.98	4.78	4.88
	Jane introduced **Bill** to **his** new teacher.	5.61	5.36	5.49
	Jane introduced **Bill's** new teacher to **Bill**.	3.88	3.82	3.85
	Jane introduced **Bill** to **Bill's** new teacher.	3.88	3.93	3.90
	Jane introduced **his** new teacher to **Bill**.	2.65	2.71	2.68
	Jane introduced **him** to **Bill's** new teacher.	2.00	2.62	2.30
Conjuncts				
Antecedent within subject	**Jeff** and Cindy asked the bakery to make a cake for **him**.	4.00	3.89	3.95
	Jeff asked the bakery to make a cake for **him** and Cindy.	5.04	4.87	4.96
	Jeff and Cindy asked the bakery to make a cake for **Jeff**.	4.24	4.16	4.20
	Jeff asked the bakery to make a cake for **Jeff** and Cindy.	3.45	3.29	3.37
	He and Cindy asked the bakery to make a cake for **Jeff**.	2.27	2.71	2.48
	He asked the bakery to make a cake for **Jeff** and Cindy.	2.08	2.82	2.44
	Kristin and Scott thought that a party should be given for **her**.	3.65	3.91	3.78

	Kristin thought that a party should be given for **her** and Scott.	5.04	4.71	4.88
	Kristin and Scott thought that a party should be given for **Kristin**.	3.98	4.18	4.07
	Kristin thought that a party should be given for **Kristin** and Scott.	3.16	3.47	3.31
	She and Scott thought that a party should be given for **Kristin**.	1.98	2.93	2.44
	She thought that a party should be given for **Kristin** and Scott.	2.12	2.87	2.48
Antecedent within object	Jill told **Dustin** and Sara that **he** was uninsured.	3.24	3.51	3.37
	Jill told **Dustin** that **he** and Sara were uninsured.	5.08	4.96	5.02
	Jill told **Dustin** and Sara that **Dustin** was uninsured.	4.20	3.58	3.90
	Jill told **Dustin** that **Dustin** and Sara were uninsured.	3.76	3.62	3.69
	Jill told **him** and Sara that **Dustin** was uninsured.	2.71	2.60	2.66
	Jill told **him** that **Dustin** and Sara were uninsured.	2.22	2.69	2.45
	Bill promised **Stacy** and David that **she** would be invited.	3.94	3.78	3.86
	Bill promised **Stacy** that **she** and David would be invited.	5.39	5.13	5.27
	Bill promised **Stacy** and David that **Stacy** would be invited.	4.31	3.96	4.14
	Bill promised **Stacy** that **Stacy** and David would be invited.	3.78	3.60	3.69
	Bill promised **her** and David that **Stacy** would be invited.	2.20	2.47	2.33
	Bill promised **her** that **Stacy** and David would be invited.	2.31	3.00	2.64

References

Badecker, W., & Straub, K. (1994, March). *Evidence that binding principles participate in a constraint satisfaction process*. Poster presented at the 7th CUNY Sentence Processing Conference, New York.

Berwick, R.C., & Weinberg, A.S. (1984). *The grammatical basis of linguistic performance: Language use and acquistion*. Cambridge, MA: MIT Press.

Carden, G. (1982). Backwards anaphora and discourse context. *Journal of Linguistics*, *18*, 361-387.

Carlson, G.N., & Tanenhaus, M.K. (1989). Introduction. In G.N. Carlson & M.K. Tanenhaus (Eds.), *Linguistic structure in language processing* (pp. 1-26). Dordrecht: Kluwer.

Carroll, J.M., Bever, T.G., & Pollack, C.R. (1981). The non-uniqueness of linguistic intuitions. *Language*, *57*, 368-383.

Chien, Y.-C., & Wexler, K. (1987). Children's acquisition of the locality condition for reflexives and pronouns. *Papers and Reports on Child Language Development*, 25.

Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht: Foris.

Chomsky, N. (1982). *Some concepts and consequences of the theory of government and binding*. Cambridge, MA: MIT Press.

Chomsky, N. (1986). *Knowledge of language: Its nature, origin and use*. New York: Praeger.

Chomsky, N. (1988). *Language and problems of knowledge*. Cambridge, MA: MIT Press.

Cinque, G. (1990). *Types of A-bar Dependencies*. Cambridge, MA: MIT Press.

Clifton, C., & Odom, R. (1966). Similarity relations among certain English sentence constructions. *Psychological Monographs*, *80*, whole no. 613.

Crain, S., & McKee, C. (1985). Acquisition of structural restrictions on anaphora. *Proceedings of the Sixteenth Annual Meeting, North Eastern Linguistic Society*. GLSA, University of Massachusetts, Amherst.

Crawley, R.A., Stevenson, R.J., & Kleinman, D. (1990). The use of heuristic strategies in the interpretation of pronouns. *Journal of Psycholinguistic Research*, *19*, 245-264.

Evans, G. (1980). Pronouns. *Linguistic Inquiry*, *11*, 337-362.

Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.

Garnham, A. (1989). Integrating information in text comprehension: The interpretation of anaphoric noun phrases. In G. Carlson and M.K. Tanenhaus (Ed.), Linguistic structure in language processing (pp. 359-399). Dordrecht: Kluwer.

Gerken, L., & Bever, T. (1986). Linguistic intuitions are the result of interactions between perceptual processes and linguistic universals. *Cognitive Science*, *10*, 457-476.

Gordon, P.C. (1993). Computational and psychological models of discourse. In H. Brownell & Y. Joanette (Eds.), *Narrative discourse in normal aging and neurologically impaired adults* (pp. 23-46). San Diego, CA: Singular.

Gordon, P.C., & Chan, D. (1995). Pronouns, passives and discourse coherence. *Journal of Memory and Language*, *34*, 216-231.

Gordon, P.C., Grosz, B.J., & Gilliom, L.A. (1993). Pronouns, names, and the centering of attention in discourse. *Cognitive Science*, *17*, 311-347.

Gordon, P.C., & Hendrick, R. (1996). The representation and processing of co-reference in discourse. Manuscript under review.

Gordon, P.C., & Scearce, K.A. (1995). Pronominalization and discourse coherence, discourse structure and pronoun interpretation. *Memory and Cognition*, *23*, 313-323.

Grimshaw, J., & Rosen, S.T. (1990). Knowledge and obedience: The developmental status of the binding theory. *Linguistic Inquiry*, *21*, 187-222.

Grober, E.H., Beardsley, W., Caramazza, A. (1978). Factors influencing assignment of pronoun antecedents. *Cognition*, *3*, 227-243.

Grodzinsky, Y., & Reinhart, T. (1993). The innateness of binding and co-reference. *Linguistic Inquiry*, *24*, 69-102.

Grosz, B.J., Joshi, A.K., & Weinstein, S. (1983). Providing a unified account of definite noun phrases in discourse. *Proceedings of the 21st Annual Meeting of the Association for Computational Linguistics*, Cambridge, MA.

Grosz, B.J., Joshi, A.K., & Weinstein, S. (1986). *Towards a computational theory of discourse interpretation*. Unpublished manuscript.

Grosz, B.J., Joshi, A.K., & Weinstein, S. (1995). Centering: A framework for modelling the local coherence of discourse, *Computational Linguistics*, *21*, 203–226.

Grosz, B.J., & Sidner, C.L. (1986). Attention, intentions, and the structure of discourse. *Computational Linguistics*, *12*, 175-204.

Heim, I. (1983). File change semantics and the familiarity theory of definiteness. In R. Bauerle, C. Schwartze, & A. von Stechow (Eds.), *Meaning, use and interpretation of language*. Berlin: de Gruyters.

Helson, H. (1947). Adaptation-level as frame of reference for prediction of psychophysical data. *American Journal of Psychology*, *60*, 1-29.

Hendrick, R. (1988). *Anaphora in Celtic and universal grammar*. Dordrecht: Kluwer.

Hestvik, A. (1990). Against the notion governing cateogry. *Proceedings of the Ninth West Coast Conference on Formal Linguistics* (pp. 263-275). Chicago, IL: University of Chicago Press.

Higginbotham, J. (1980). Pronouns and bound variables. *Linguistic Inquiry*, *11*, 679-708.

Higginbotham, J. (1985). On semantics. *Linguistic Inquiry*, *16*, 547-593.

Huang, Cheng-Teh (1982a). *Logical Relations in Chinese and the theory of grammar*. Unpublished PhD dissertation, MIT, Cambridge, MA.

Huang, Cheng-Teh (1982b). A note on the binding theory. *Linguistic Inquiry*, *14*, 554-561.

Kamp, H., & Reyle, U. (1993). *From discourse to logic: Introduction to model theoretic semantics of natural language, formal logic and discourse representation theory*. Dordrecht: Kluwer.

Kintsch, W., & van Dijk, T.A. (1978). Toward a model of text comprehension and production. *Psychological Review*, *85*, 363-394.

Larson, R. (1988). On the double object construction. *Linguistic Inquiry*, *19*, 335-392.

Larson, R. (1990). Double objects revisited: Reply to Jackendoff. *Linguistic Inquiry*, *21*, 589-632.

Lasnik, H. (1976). Remarks on Co-reference. *Linguistic Analysis*, 2.

Lebeaux, D. (1985). Locality and anaphoric binding. *Linguistic Review*, *4*, 343-363.

Lust, B. (Ed.). (1986). *Studies in the acquisition of anaphora*. Dordrecht: Reidel.

McCloskey, J. (1990). Irish resumptive pronouns. In R. Hendrick (Ed.), *Syntax and semantics*, *23*, 199-248.

Nicol, J., & Swinney, D. (1989). The role of structure in co-reference assignment during sentence processing. *Journal of Psycholinguistic Research*, *18*, 5-19.

Parducci, A. (1956). Direction of shift in the judgment of single stimuli. *Journal of Experimental Psychology*, *51*, 169-178.

Parducci, A. (1984). Perceptual and judgmental relativity. In V. Sarris & A. Parducci (Eds.), *Perspectives in psychological experimentation* (pp. 135-149). Hillsdale, NJ: Erlbaum.

Parsons, T. (1990). *Events in the semantics on English: A study in subatomic semantics*. Cambridge, MA: MIT Press.

Postal, P. (1971). *Cross over phenomena*. New York: Holt, Rinehart and Winston.

Reinhart, T. (1976). *The syntactic domain of anaphora*. Cambridge, MA: MIT.

Reinhart, T. (1981). Definite NP anaphora and c-command domains. *Linguistic Inquiry*, *12*, 605-636.

Rizzi, L. (1990). *Relativized minimality*. Cambridge, MA: MIT Press.

Sheldon, A. (1974). The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior*, *13*, 272-281.

Sidner, C. (1983). Focusing in the comprehension of definite anaphora. In M. Brady & R. Berwick (Eds.), *Computational models of discourse* (pp. 267-330). Cambridge, MA: MIT Press.

Solan, L. (1983). *Pronominal reference: Child language and the theory of grammar*. Dordrecht: Reidel.

Stowell, T., & Lasnik, H. (1991). Weakest crossover. *Linguistic Inquiry*, *22*, 687-720.

van Riemsdijk, H., & Williams, E. (1986). *Introduction to the theory of grammar*. Cambridge, MA: MIT Press.

Wasow, T. (1979). *Anaphora in generative grammar*. Ghent: E. Story Scientia.

Wexler, K., & Chien, Y.-C. (1985). The development of lexical anaphors and pronouns. *Papers and Reports on Child Language Development*, 24. Stanford University, Stanford, CA.