

# **Processing of Reference and the Structure of Language: An Analysis of Complex Noun Phrases**

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Five experiments used self-paced reading time to examine the ways in which complex noun phrases (both conjoined NPs and possessive NPs) influence the interpretation of referentially dependent expressions. The experimental conditions contrasted the reading of repeated names and pronouns referring to components of a complex NP and to the entire complex NP. The results indicate that the entity introduced by a major constituent of a sentence is more accessible as a referent than the entities introduced by component noun phrases. This pattern of accessibility departs from the advantage of first mention that has been demonstrated using probe-word recognition tasks. It supports the idea that reduced expressions are interpreted as referring directly to prominent entities in a mental model whereas reference by names to entities that are already represented in a mental model is mediated by additional processes. The same interpretive processes appear to operate on coreference within and between sentences.

## **INTRODUCTION**

Communication through language involves sharing some part of our subjective world with others. This intuition is expressed theoretically in work on mental models (Johnson-Laird, 1983) which describes many aspects of cognition as consisting of operations on subjective worlds that

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are models of real or possible worlds. In the case of language comprehension, this involves building a mental model of the semantic content of linguistic input that is heard or read (Garnham & Oakhill, 1996). This resulting model consists of the semantic entities that are referred to by the linguistic input, plus the relations between those entities. Such a model will be simple to build and to use when successive portions of the linguistic input make reference to the same semantic entities in an orderly manner. This approach is consistent with the general view that the local coherence of language depends on continued reference to a small number of things (Garrod & Sanford, 1982; Grosz, Joshi, & Weinstein, 1983, 1995; Halliday & Hassan, 1976; Kintsch & van Dijk, 1978). Thus, researchers interested in the coherence of language have given considerable attention to the study of anaphora—the process by which a linguistic expression derives its meaning from an earlier, or *antecedent*, linguistic expression. The antecedent introduces a semantic entity into the world of the discourse and the anaphoric expression makes reference to that entity. In this way, the antecedent and anaphoric expressions are *coreferential*—they make reference to the same entity.

The relative contributions of structural and semantic factors to the interpretation of referential expressions has been a topic of continuing investigation (e.g. Garnham, Oakhill, & Cruttenden, 1992; Grober, Beardsley, & Caramazza, 1978). We take the position that the coherence of the mental model of a text reflects the consistency of the semantic relationships expressed in the text. However, we also believe that the referential processes that build that model are strongly influenced by the structure of language, both at the level of the syntactic organisation of sentences (Chomsky, 1981; Reinhart, 1976) and at the level of the structural organisation of local discourse segments (Grosz et al., 1983; Grosz, Joshi, & Weinstein, 1995). These structural factors constrain the linguistic form of referring expressions, influencing whether they appear as reduced, referentially dependent linguistic forms (such as pronouns) or unreduced, referentially independent linguistic forms (such as names or descriptions). A growing body of experimental research (Badecker & Straub, 1994; Gordon, Grosz, & Gilliom, 1993; Hudson-D'Zmura, 1988; Hudson, Tanenhaus, & Dell, 1986; Nicol & Swinney, 1989) shows that such constraints on linguistic form play an important role in language comprehension. The present research examines comprehension of coreference involving complex noun phrases, both conjoined NPs and possessive NPs. It does so in order to explore how the structure of sentences and of discourse influence coreferential interpretation. In doing so, it shows that syntactic organisation is more important in coreferential interpretation than is order of mention (cf. Gernsbacher, 1990; Walker & Prince, 1996).

## Discourse Prominence Theory

We (Gordon & Hendrick, 1998) have developed a model that provides an integrated account of the interpretation of different types of referring expressions both within sentences and between sentences. The model is developed within the formalism of Discourse Representation Theory (Kamp & Reyle, 1993) which is a theory of the semantics of evolving discourse. Conceptually, the model also draws on centering theory (Grosz et al., 1983, 1995), which attempts to understand coherence in segments of discourse.

In the Kamp and Reyle (1993) formalism that we employ, construction rules operate on syntactic representations in order to build a representation of a discourse. A construction rule consists of a triggering condition and a set of instructions for operations on the discourse model (Kamp & Reyle, 1993). We present a specific set of construction rules for interpreting referential expressions in order to account for both the distribution and comprehension of different types of referential expressions, and to account for coreference within and between sentences. The construction rule for proper names is triggered by the occurrence of a proper name and it then posits a new discourse referent in the universe of the discourse with the name predicated of it. The construction rule for pronouns is triggered by the occurrence of a pronoun and it then searches the discourse referents in order of prominence for a suitable antecedent (as indicated by matches on gender, number, and animacy). The contrast between these two rules embodies the idea that the primary function of names is to establish reference in relation to knowledge and the world, whereas the primary function of pronouns is to make reference within the circumscribed domain of the current universe of a discourse. Accordingly, a pronoun naturally creates coreference whereas the repetition of a name does not. Coreference between two names can only be achieved through an additional construction rule of equivalence. This rule is triggered by the presence in the discourse model of two entities predicted on the same name (or other information that could establish equivalence); it introduces a new condition in the discourse model that equates the two entities. Establishing coreference between two names is therefore a cumbersome process, which explains why anaphoric reference with a name is judged as less acceptable than anaphoric reference with a pronoun except under very specific circumstances (Gordon & Hendrick, 1997) and why repeated names can cause slower reading times than pronouns (Gordon et al., 1993).

The idea that discourse referents are ordered in prominence comes from the construct in Centering Theory of a set of forward-looking centres (Grosz et al., 1983, 1995). We incorporate this construct into the Kamp

and Reyle (1993) framework by theorising that semantic prominence in the discourse universe is strongly influenced by the syntactic role of the expression that introduces a discourse referent. To do so, we formulate a general principle of syntactic prominence that influences the dynamics of semantic prominence in the discourse universe. Pronominal reference to a prominent entity is easier than to a nonprominent entity because the construction rule for pronouns searches for a referent by examining the discourse entities in order of prominence. Reference with a repeated name to a prominent entity is harder than to a nonprominent entity because the construction rule for names introduces a new entity, which the name is predicated on, into the discourse universe. Having the same name predicated on two distinct entities causes greater semantic incoherence when the entities involved are prominent because the process of equating entities operates most effectively with nonprominent entities.

This notion of syntactic prominence can account for coreference phenomena that occur both between sentences and within sentences. Studies of self-paced reading time and of eye-tracking have demonstrated the *repeated-name penalty*, where sentences or phrases are read more slowly when they contain repeated names as compared to when they contain pronouns, is greater when the antecedent was the grammatical subject of the preceding sentence rather than the grammatical object (Gordon et al., 1993; Kennison & Gordon, 1997). Studies of within-sentence coreference (Gordon & Hendrick, 1997) have shown that the judged acceptability of pronominal coreference increases when the antecedent is the head of its noun phrase, and that this effect is greater when the antecedent is the grammatical subject rather than a grammatical object; further, the judged acceptability of coreference with a repeated name shows the reverse pattern of syntactic influences. This effect appears to extend to the interpretation of ambiguous pronouns, as many heuristic strategies for pronoun interpretation (Crawley, Stevenson, & Kleinman, 1990; Frederiksen, 1981; Grober et al., 1978) favour interpretation of an ambiguous pronoun as coreferential with an antecedent that is syntactically prominent and therefore could not be coreferential with a subsequent name (Gordon & Hendrick, 1997). Finally, studies of language use confirm the preference for pronominal, rather than repeated-name, coreference when the antecedent is syntactically prominent (Brennan, 1995; Chafe, 1976; Fletcher, 1984; Marslen-Wilson, Levy, & Tyler, 1982).

Our model (Gordon & Hendrick, 1998) has both similarities and differences with other approaches to the processing of reference in discourse. The notion of representations of a universe of discourse, adapted from Kamp and Reyle (1993) is similar to Johnson-Laird's (1983) notion of mental models. The idea that reduced expressions are interpreted with respect to the discourse universe, whereas full expressions

are interpreted with respect to general knowledge is similar to how these two types of expressions relate to discourse focus in the work of Garrod and Sanford (1982); this similarity stems in part from the influence of the work of Grosz (1977) on our work and on theirs. Our model differs from Garrod and Sanford's in explicitly assigning an important role to syntactic factors in the interpretation of referring expressions. The notion that a discourse model is constructed during comprehension is broadly similar to the notion advanced by Gernsbacher (1989, 1990, 1996) that language comprehension involves *structure building*. Our model differs substantially from hers in its characterisation of how reduced and full expressions are interpreted and in the importance it assigns to syntactic structure as compared to sequential structure.

The present experiments test key predictions of our model (Gordon & Hendrick, 1998), and in specific cases contrast the model's predictions with those of other models. In particular, the experiments contrast the importance in coreference that we attribute to constituent structure with that attributed to order of mention. The idea that expressions that are first in a sequence are more highly accessible for subsequent reference than are expressions that follow has had appeal both in psycholinguistics (Gernsbacher, 1990, 1996) and in computational linguistics (Walker & Prince, 1996). Gernsbacher and her colleagues (1990, 1996; Gernsbacher & Hargreaves, 1988; Gernsbacher, Hargreaves, & Beeman, 1989; Carreiras, Gernsbacher, & Villa, 1995) have argued that results from probe-word experiments support the "advantage of first mention", that first mentioned participants in a narrative are more highly accessible than subsequently mentioned participants. Walker and Prince (1996) have taken examples from natural corpora to support a working hypothesis that they call the "complex NP assumption"; it states that when an NP evokes multiple participants then the ordering of prominence is from left to right within the NP. In many naturally occurring instances, order of mention and grammatical role vary together to cause the entity referred to by the subject of a sentence to be the most prominent entity in the discourse. The experiments in the present paper use complex noun phrases consisting of conjoined NPs and possessive NPs in order to dissociate the effects of grammatical role and order of mention on the processing of referential expressions; these effects are measured using self-paced reading time.

## EXPERIMENTS 1a AND 1b

These experiments examined reading times for clauses containing pronouns or names that were coreferential with a name in the immediately preceding clause. Table 1 shows sample stimuli in Experiment 1a, where

TABLE 1

Sample Passages Used in Experiment 1a. The Critical Second Frame, for which Reading Times are Reported, is Boxed

<i>No Conjunct</i>	<i>Conjunct</i>
John went to the store so that <b>he/John</b> could buy candy.	John went to the store so that <b>he/John</b> and Mary could buy candy.
The store was closed.	The store was closed.

the coreferential expression was either embedded in a conjoined NP or was not. Table 2 illustrates the stimuli used in Experiment 1b, where the antecedent name was either embedded in a conjoined NP or was not. The experiments addressed two goals. The first was to see whether a repeated-name penalty, where repeated names lead to slower reading times than pronouns, is observed for coreference within a sentence as it has been shown to occur for coreference between sentences (Gordon et al., 1993).

The second goal was to test a prediction of our model of referential processing (Gordon & Hendrick, 1998) concerning the effect of complex noun phrases, particularly conjoined NPs, on the ease of establishing coreferential interpretations. In order to account for patterns of grammaticality, we proposed a construction rule for pronouns which searches through the discourse referents in order of prominence in order to find a suitable referent for a pronoun. When the subject of a sentence is a conjoined NP, the collective entity referred to by the conjoined NP is the most prominent entity in the discourse model. The construction rule for pronouns will therefore consider this entity first as a possible referent for a pronoun, and must reject that entity and consider a less prominent entity in order to find a suitable antecedent. This leads to the prediction that a repeated-name penalty should not be observed when the referent of a singular pronoun was introduced as part of a conjoined-NP antecedent.

Results of an experiment by Garnham (1989) suggest that this prediction may not be correct. Garnham looked at reading times for

TABLE 2

Sample Passages Used in Experiment 1b. The Critical Second Frame, for which Reading Times are Reported, is Boxed

<i>No Conjunct</i>	<i>Conjunct</i>
John went to the store so that <b>he/John</b> could buy candy.	John and Mary went to the store so that <b>he/John</b> could buy candy.
The store was closed.	The store was closed.

sentences containing a repeated definite description (e.g. "The denim") as a function of whether the antecedent expression was embedded in a conjoined NP (e.g. "The denim and the velvet") or not. He found that having a conjoined-NP antecedent elevated reading times for the sentence containing the coreferential expression, even though the repeated definite expression seemed more natural in that case than when its antecedent was not embedded in a conjoined NP. The present experiment provides a comparison of times for sentences containing both repeated full expressions and reduced pronominal expressions, a comparison not investigated by Garnham (1989).

## Method

*Subjects* Forty students at the University of North Carolina served as subjects in each experiment. They received course credit in Introductory Psychology for their participation.

*Stimulus Materials.* A set of 40 passages was constructed for the experiment. Four versions of each of the passages in each set were constructed as shown in the tables. In Experiment 1a, the subject of the first clause of the first sentence introduced a single character by name. The subject of the second clause contained an expression that was coreferential with the subject of the first clause. This coreferential expression was either a pronoun or a name, and was either the head of the subject noun phrase or was embedded in a conjoined noun phrase that was the head of the subject noun phrase. The second sentence of the passage did not mention either of the two characters, and was included so that the critical second clause would not be at the end of the passage. The characters in each passage had names that were stereotypically of different sex. A total of four conditions were used as shown in Table 1.

In Experiment 1b, passages from Experiment 1a were modified so that in the conjoined-NP condition, the antecedent noun phrase that introduced the character(s) was the subject of the first clause. The subject of the second clause was always a simple noun phrase consisting of a pronoun or a name. The four experimental conditions are illustrated in Table 2. (Otherwise, the stimuli, design and procedure were the same as in Experiment 1a.)

A set of 96 filler passages was also constructed. These passages instantiated the same sorts of mundane themes as the experimental passages, and like the experimental passages they included named characters. However, the fillers included some syntactic constructions that were not appropriate to the experimental passages and did not manipulate noun phrase configuration. A true/false question was included

for each passage in order to ensure that subjects read the passages. The questions were such that readers could determine the correct answers without remembering names of the characters in the passage.

*Design and Procedure.* The 40 experimental passages were grouped with the 96 filler passages into an initial trial block of 16 passages, and 5 experimental blocks of 24 passages each. The first block served to familiarise subjects with the task and contained only filler passages. Each of the subsequent blocks contained 16 filler passages and 8 experimental passages (two in each condition). Four groupings of the experimental passages were constructed so that a given subject read each experimental passage once and read equal numbers of passages in each of the four conditions. Across subjects, each passage occurred equally often in each condition.

Subjects were tested on a personal computer. They initiated each trial by pressing the space bar. During a trial, the clauses or sentences (corresponding to each line as they appear in Tables 1 and 2) from a passage were presented one at a time in the centre of the screen. To move on to the next sentence, subjects had to press the space bar. Instructions to the subjects emphasised reading at a natural pace. After the subject had read the passage, the screen went blank for one second. Then, the true/false comprehension question appeared in the centre of the screen. Subjects indicated their responses by pressing appropriately labelled keys. Feedback was only given on trials in which the response to the question was incorrect. At the end of each block, subjects were informed how many questions they had answered incorrectly.

## Results

The results of Experiment 1a are shown in Table 3, which shows the mean reading time for the critical second clause in each of the four experimental conditions. After examination of response distributions and considerations of plausibility, times less than 400 msec and greater than 8000 msec were deemed outliers and were excluded from all calculations. Such outliers constituted 0.63% of the observations. Analysis of variance showed that reading times were longer in the conjoined-NP condition than in the

TABLE 3  
Mean Reading Time (msec) for Critical Frame in Experiment 1a

	<i>Singular Noun Phrase</i>	<i>Conjoined Noun Phrase</i>
Name	1928	2411
Pronoun	1747	2326



no-conjunct condition [ $F_1(1,39) = 119.2, P < .001; F_2(1,39) = 116.1, P < .001$ ]. This finding is not surprising and undoubtedly stems at least in part from the fact that clauses in the conjoined-NP condition were two words longer than clauses in the no-conjunct condition. Reading times were also longer when the coreferential expression was realised with a name as compared to when it was realised with a pronoun [ $F_1(1,39) = 12.3, P < .001; F_2(1,39) = 9.8, P < .005$ ]. The interaction between the conjoined-NP manipulation and the manner of realisation manipulation was not significant [ $F_1(1,39) = 1.1, P = .308; F_2(1,39) = 2.3, P = .14$ ].

The results of Experiment 1b are shown in Table 4, which shows the mean reading time for the critical second clause in each of the four experimental conditions. Outliers were excluded using the same criteria as in the previous experiment, and constituted 1.19% of the observations. Analysis of variance showed that reading times were longer in the conjoined-NP condition than in the no-conjunct condition [ $F_1(1,39) = 7.98, P < .01; F_2(1,39) = 9.16, P < .005$ ]. Unlike the previous experiment, this effect is not confounded with the number of words being read. It involves a comparison of the time to read the exact same second clause as a function of whether the subject noun phrase of the first clause was a conjoined NP or not. Reading times were not significantly different when the coreferential expression was realised with a name as compared to when it was realised with a pronoun [ $F_1(1,39) = 2.41, P = .128; F_2(1,39) = 1.33, P = .256$ ]. The interaction between the conjoined-NP manipulation and the manner of realisation manipulation was significant [ $F_1(1,39) = 17.1, P < .001; F_2(1,39) = 7.38, P < .01$ ]. A contrast showed that in the no-conjunct condition, reading times were longer in the name condition as compared to the pronoun condition [ $t_1(39) = 4.45, P < .001; t_2(39) = 2.67, P < .02$ ]. A second contrast showed that in the conjoined-NP condition, the shorter reading times observed in the name condition as compared to the pronoun condition fell short of significance [ $t_1(39) = 1.69, P = .10; t_2(39) = 1.02, P > .10$ ].

## Discussion

The results of Experiment 1a support our model of referential processing (Gordon & Hendrick, 1998). Repeated-name penalties were observed for

TABLE 4  
Mean Reading Time (msec) for Critical Frame in Experiment 1b

	<i>Singular Noun Phrase</i>	<i>Conjoined Noun Phrase</i>
Name	1931	1920
Pronoun	1757	1986

cases of intrasentential coreference as we have previously found them in cases of intersentential coreference (Gordon et al., 1993). According to the model, the repeated-name penalty occurs because coreferential interpretation of pronouns and names is accomplished through different mechanisms. The construction rule for pronouns seeks a referent directly in the current universe of a discourse and thus naturally leads to coreferential interpretation. The construction rule for names posits a new entity predicated on the name; coreference is only established through the construction rule for equivalence which is triggered by the presence in the discourse universe of two entities predicated on the same name. Thus, the construction rule for pronouns establishes coreference with fewer steps than the construction rule for names, and therefore leads to the expectation that coreference will be achieved more quickly when a pronoun refers to an entity that is prominent in the discourse universe than when a name refers to such an entity. The results of this study bear out this expectation.

The results of Experiment 1b also support the model of referential processing advanced by Gordon and Hendrick (1997, 1998). The effect of linguistic form (pronoun vs. name) interacted significantly with whether the antecedent was embedded in a conjunct. When the antecedent was embedded in a conjunct, no repeated-name penalty was observed and there was a nonsignificant tendency for reading times to be slower in clauses containing pronouns as compared to names. This supports the notion advanced by Gordon and Hendrick (1997, 1998) that pronouns are interpreted more easily when their referents are prominent in the universe of discourse.

The results of Experiment 1b on repeated names differ from those reported by Garnham (1989) for repeated definite descriptions. His results showed that a conjoined-NP antecedent elevated reading times for sentences with a repeated definite description, whereas we found no such elevation for repeated names. It is not clear whether this difference is due to a difference between repeated names and repeated definite descriptions or to some other factor. Our investigation goes beyond that of Garnham (1989) in also providing comparisons to reduced, pronominal expressions. These comparisons support the notion that the advantage of pronouns over names can be eliminated if the referent of the pronoun is not introduced in a linguistically prominent position.

## EXPERIMENT 2

The first goal of this experiment was to test more directly the idea that having the antecedent embedded in a conjoined NP eliminates the repeated-name penalty in subsequent reference because the collective

TABLE 5

Sample Passages Used in Experiment 2. The Critical Second Frame, for which Reading Times are Reported, is Boxed

John went to the store so that <b>he</b> could buy candy.	John and Mary went to the store so that <b>they/he/John</b> could buy candy.
The store was closed.	The store was closed.
John went to the store. <b>He</b> wanted to buy candy.	John and Mary went to the store. <b>They/he/John</b> wanted to buy candy.
The store was closed.	The store was closed.

entity referred to by the conjoined NP is the most prominent entity in the discourse model (Gordon & Hendrick, 1997, 1998). This idea was tested by measuring reading times for text containing the plural pronoun “they” subsequent to a conjoined NP. These times were compared to times for reading singular pronouns and names subsequent to conjuncts, and also to times for reading singular pronouns following names that are not in conjuncts. Table 5 illustrates the stimuli used in the study. If the collective entity referred to by a conjoined NP in subject position is the most prominent entity in the discourse universe, then reading times should be shorter for plural pronouns following conjoined-NP antecedents than for either singular pronouns or names. Further, reading times for plural pronouns should not differ from reading times for singular pronouns following simple noun phrases in subject position because in both cases pronominal reference is being made to the most prominent entity in the discourse model.<sup>1</sup>

In the present case, the predictions of the Gordon and Hendrick (1997, 1998) model differ from those based on Gernsbacher’s (1989, 1990, Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989) concept of the advantage of first mention. According to this concept, the participant who is mentioned first in a discourse or sentence has a “privileged place in the comprehenders’ mental representations” and because of this “are affected

<sup>1</sup> Garrod and Sanford (1982) present a brief report of an experiment that is similar to the current one, in that it examines reading times for sentences containing singular pronouns, plural pronouns and repeated names following sentences that contain an antecedent consisting of a conjunction of two names. The discussion of the experiment does not provide details about the method nor does it present statistical analyses of the results. Garrod and Sanford (1982) focus their discussion on the interaction of syntactic position and form of referring expression in the sentence containing the coreferential expression. They do not indicate whether there are significant differences between the different types of (co)referring expressions when they occupy the position of grammatical subject, the position they have in the current expression.

in a special way by the mechanisms that improve referential access: They are more resistant to being suppressed and they are more strongly enhanced” (Gernsbacher, 1989, p. 141). This hypothesis leads to the expectation that the participant referred to by the first noun phrase (NP) in the conjoined-NP would be more accessible than the collective entity referred to by the entire conjoined NP as the first NP is “mentioned” first. If the accessibility of participants determines the ease of subsequent coreference, then this leads to the prediction that a singular pronoun referring to the participant introduced by the first NP of the conjoined NP would be more accessible than the collective entity introduced by the entire conjunct. Similarly, the complex NP hypothesis advanced by Walker and Prince (1996) would also seem to predict that the first mentioned (leftmost) entity would be the most accessible. These predictions differ from those made by our model (Gordon & Hendrick, 1998).

The second goal of this experiment was to compare the effect of different types of coreference within and between sentences. In the model developed by Gordon and Hendrick (1997, 1998) the same construction rules are used for interpreting referential expressions both within sentences and between sentences within a discourse segment. This leads to the prediction that the different patterns of coreference should have the same effects within and between sentences.

## Method

*Subjects.* Eighty students at the University of North Carolina served as subjects; half participated in the within-sentence condition and half in the between-sentence condition. They received course credit in Introductory Psychology for their participation.

*Stimulus Materials.* The experimental passages varied in noun phrase configuration and in terms of whether coreference was between expressions located in a main and an embedded clause or between expressions located in distinct sentences. Noun phrase configuration was determined by whether the antecedent was a conjoined NP or a simple noun phrase and by whether the second referring expression was a singular pronoun, a name, or a plural pronoun. A total of eight conditions were used as shown in Table 5. Two sets of 40 passages were constructed for the experiment—one set of two-sentence passages and one set of three-sentence passages. The two sets were the same except that the two-sentence versions joined the first two sentences of the three-sentence versions through the use of a connective, as shown in Table 5. Four versions of each of the 40 passages in each set were constructed as shown in the table. The versions resulted from the type of antecedent that was the subject of the first clause (or sentence)

and the form of the coreferential expression in the second clause or sentence. The four versions were: no-conjunct/singular pronoun, conjunct/plural pronoun, conjunct/singular pronoun, and conjunct/name. A second set of fillers consisting of three-sentence passages was constructed.

*Design and Procedure.* The domain of coreference (within vs. between sentence) was manipulated between subjects, whereas the other factors were manipulated within subjects. Otherwise, the design and procedure were the same as in the previous experiments.

## Results

Table 6 shows the mean reading time in each experimental condition for the critical second frame which corresponds to the second clause when coreference is between main and subordinate clauses and the second sentence when coreference is between sentences. Outliers were excluded according to the same criteria used in the previous experiments; 0.37% of the observations were treated in this way. In addition, an error was found in one of the passages and it was eliminated from all conditions. A four (noun phrase configuration) by two (within sentence/between sentence) analysis of variance was performed on the data. The main effect of noun phrase configuration was significant [ $F_1(3,234) = 10.1, P < .001; F_2(3,114) = 8.5, P < .001$ ]. The main effect of whether coreference was within or between sentences was not significant [ $F_1(1,78) P < 1; F_2(1,38) < 1$ ], nor did this factor interact significantly with noun phrase configuration [ $F_1(1,78) P < 1; F_2(1,38) < 1$ ]. A planned contrast showed that reading times were significantly faster when a pronoun coreferred with the entity introduced by the subject noun phrase as compared to when a pronoun or name coreferred with an individual member of a conjoined-NP [ $t_1(78) = 3.95, P < .005; t_2(38) = 3.61, P < .005$ ]. There was no significant difference in reading times between the no conjunct/singular pronoun and conjunct/plural pronoun conditions [ $t_1(78) = .25, P > .10; t_2(38) = .23, P > .10$ ]. There was also no significant difference in reading times between the conjunct/singular pronoun and conjunct/name conditions [ $t_1(78) = .58, P > .10; t_2(38) = .53, P > .10$ ].

TABLE 6  
Mean Reading Time (msec) for Critical Frame in Experiment 2

	<i>Simple NP/ Singular Pronoun</i>	<i>Conjunct/ Plural Pronoun</i>	<i>Conjunct/ Singular Pronoun</i>	<i>Conjunct/ Name</i>
Within Sentence	1684	1678	1864	1836
Between Sentences	1689	1724	1863	1827

## Discussion

The results of the experiment provide clear support for the hypothesis (Gordon & Hendrick, 1997, 1998) that the collective entity realised in subject position by a conjoined NP is more prominent and accessible than its component entities. When the antecedent was a conjoined NP, reading times were faster for a plural pronoun than for a singular pronoun or a repeated name, indicating that reference to the collective entity was most quickly understood. Those reading times for clauses containing plural pronouns did not differ from those observed for singular pronouns coreferring with an antecedent that was a simple NP, indicating that the entity referred to by the subject of a sentence is the most accessible for subsequent reference regardless of whether it is a simple NP, or a complex NP consisting of a conjoined NP. These results are not what would be expected if the ease of subsequent reference is determined by the advantage of first mention (Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989) or by left-to-right order of entities (Walker & Prince, 1996). Our findings showed that reference to the first mentioned participant (i.e. the first named individual in the conjoined NP) was understood more slowly than reference to the collective entity created by combining both participants in the conjoined NP.

The results of the experiment also showed that the impact of the pattern of coreference on reading time did not differ as a function of whether coreference occurred within or between sentences. This supports the thesis (Gordon & Hendrick, 1997, 1998) that the same construction rules are used for establishing coreference within and between sentences.

## EXPERIMENT 3

The goal of this experiment is to provide a further test of the advantage of first mention by examining whether reference to the first mentioned character in a conjoined NP is achieved more easily than reference to the second mentioned character in a conjoined NP. Psycholinguistic research exploring the advantage of first mention has not contrasted individual entities to collective entities, as we did in the previous experiment, but rather has compared different individual entities in different positions in a sentence, including within conjoined NPs (Gernsbacher & Hargreaves, 1988; Carreiras et al., 1995). Similarly, the complex NP assumption of Walker and Prince (1996) applies more directly to a comparison of reference to the names within a complex NP than it does of a single name to the entire NP.

The experiment measures reading time for clauses and sentences such as those shown in Table 7, which include plural pronouns, singular pronouns that agree in gender with the first character in the conjoined NP and

TABLE 7

Sample Passages Used in Experiment 3. The Critical Second Frame is Boxed

John and Mary went to the store

so that **they/he/she** could buy candy.

The store was closed.

John and Mary went to the store.

**They/he/she** wanted to buy candy.

The store was closed.

singular pronouns that agree in gender with the second character in the conjoined NP. Our analysis of the importance syntactic factors in coreference (Gordon & Hendrick, 1998), as well as the results of the preceding experiment lead to the expectation that the fastest reading times should be observed with the plural pronouns. Research on the advantage of first mention leads to the expectation that faster reading times should be observed with pronouns that agree with the first named character as compared to the second named character.

## Method

*Subjects.* Forty-two students at the University of North Carolina served as subjects; half participated in the within-sentence condition and half in the between-sentence condition. They received course credit in Introductory Psychology for their participation.

*Stimulus Materials, Design and Procedure.* Table 7 illustrates the conditions in the experiment. The experimental passages were the same as in the preceding experiment with the following exceptions: The subject of the first clause or sentence was always a conjoined NP consisting of two names. The critical referring expression in the second clause or sentence could either be a plural pronoun, a singular pronoun that agreed in gender with the first name in the conjoined NP, or a singular pronoun that agreed in gender with the second name in the conjoined NP. One of the 40 experimental passages was eliminated so that the number of stimuli could be evenly divided by the number of conditions. Within-sentence versus between-sentence coreference was again manipulated between subjects; other aspects of the design and procedure were the same as in the preceding experiment.

## Results

Table 8 shows the mean reading time in each experimental condition for the critical frame in which the pronoun was manipulated. Outliers constituted 0.18% of the observations. A three (reference of pronoun) by two (within/between sentence) analysis of variance was performed. There was a main effect of pronoun [ $F_1(2,80) = 3.53, P < .05; F_2(2,152) = 3.2, P < .05$ ]; it did not interact significantly with the within/between-sentence manipulation [ $F_1(2,80) < 1; F_2(2,152) < 1$ ]. A planned comparison showed that reading times were significantly faster with a plural pronoun than with the average of pronouns that agreed in gender with the first or second named characters [ $t(41) = 2.56, P < .02; t(38) = 2.47, P < .02$ ]. A second planned comparison showed that there was not a significant difference between reading times for critical frames with pronouns that agreed in gender with the first named character and those that agreed in gender with the second named character [ $t(41) = .04, P > .25; t(38) = .04, P > .25$ ].

## Discussion

The results of the experiment show that when two characters are introduced with a conjoined NP, subsequent clauses or sentences with plural pronouns are read more quickly than matched clauses with singular pronouns that agree in gender with either the first or second character in the conjoined NP. This finding is consistent with the results of the previous experiment and with our theoretical analysis of complex NPs (Gordon & Hendrick, 1998).

The results of the experiment showed no significant difference in reading times for clauses or sentences containing pronouns that agreed in gender with the first character as compared to those that agreed in gender with the second character. The hypothesis of the advantage of first mention (Gernsbacher, 1990) and the complex NP assumption (Walker & Prince, 1996) lead to the expectation that reference to the first character should be understood more easily than reference to the second character.

TABLE 8  
Mean Reading Time (msec) for Critical Frame in Experiment 3

	<i>Plural Pronoun</i>	<i>Singular Pronoun Agreeing with First Antecedent</i>	<i>Singular Pronoun Agreeing with Second Antecedent</i>
Within Sentence	1659	1759	1776
Between Sentences	1795	1898	1875



The absence of such an effect on reading time contrasts with the many demonstrations of the effect that have been obtained using probe word recognition methodology (Careiras et al., 1995; Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989). The present experiments, as well as others, have shown that reading time methodology is a sensitive measure of referential processing. This can be seen in the difference between plural pronouns and singular pronouns in this and the preceding experiment; it can also be seen in the difference in the preceding experiment in the reading times for singular pronouns following singular as compared to plural antecedents. Reading-time measures and probe word measures appear to be tapping different processes, a topic we return to in the General Discussion.

## EXPERIMENT 4

The goal of this experiment (and the next one) is to extend the exploration of coreference involving complex NPs, begun with conjoined NPs in the previous experiments, to the domain of possessive noun phrases. According to our model (Gordon & Hendrick, 1998), interpretation of a possessive NP leads to the introduction in the discourse model of entities corresponding to the possessed entity and the possessor entity, with the possessed entity being the more prominent of the two because it is determined by the entire NP. Such prominence of the possessed entity favours coreference with a subsequent pronoun and disfavors coreference with a subsequent name. The current experiment uses self-paced reading time methodology to test this prediction. Further, it examines whether the same pattern is observed within and between sentences as would be expected if the same processes were used for both intrasentential and intersentential coreference. A total of eight conditions, illustrated in Table 9, were included in the experiment.

TABLE 9  
Sample Passages Used in Experiment 4. The Critical Second Frame is Boxed

Bill owns a lake house	Bill owns a lake house.
where <b>his/Bill's</b> aunt likes to go swimming.	<b>His/Bill's</b> aunt likes to go swimming there.
It's nice to live beside a lake.	It's nice to live beside a lake.
Bill's aunt owns a lake house	Bill's aunt owns a lake house.
where <b>he/Bill</b> likes to go swimming.	<b>He/Bill</b> likes to go swimming there.
It's nice to live beside a lake.	It's nice to live beside a lake.

## Method

*Subjects.* Eighty students at the University of North Carolina served as subjects. They received course credit in Introductory Psychology for their participation. None of the subjects had participated in the previous experiments.

*Stimulus Materials, Design and Procedure.* The experimental conditions are illustrated in Table 9. The factor of within-sentence versus between-sentence coreference was manipulated between subjects, and the factors of form of referring expression and position of the possessive were manipulated within subjects. Otherwise, the stimuli, design and procedure were the same as in the previous experiments.

## Results

Table 10 shows mean reading times for the critical frame consisting of the second clause or sentence. Outliers were excluded according to the same criteria used in the previous experiments; 0.11% of the observations were treated in this way. Reading times for the critical frames were higher when they contained repeated names as compared to pronouns [ $F_1(1,78) = 9.05$ ,  $P < .005$ ;  $F_2(1,78) = 7.48$ ,  $P < .01$ ]. However, this effect showed a significant interaction with the location of the possessive [ $F_1(1,78) = 8.94$ ,  $P < .005$ ;  $F_2(1,78) = 5.50$ ,  $P < .025$ ]. Planned comparisons showed that there was a significant repeated name penalty for simple NP/possessive sequences [ $t_1(78) = 4.33$ ,  $P < .001$ ;  $t_2(78) = 3.78$ ,  $P < .001$ ], but not for possessive/simple NP sequences [ $t_1(78) = 0.11$ ,  $P > .25$ ;  $t_2(78) = 0.09$ ,  $P > .25$ ]. No interactions involving the factor of within- versus between-sentence coreference were significant.

## Discussion

The results indicate that when an antecedent expression in subject position is a simple NP, subsequent coreference with it is comprehended more

TABLE 10  
Mean Reading Time (msec) for Critical Frame in Experiment 4

NP1	Simple NP		Possessive	
	Possessive Pronoun	Possessive Name	Pronoun	Name
NP2				
Within Sentence	1986	2196	1700	1747
Between Sentences	2117	2219	1769	1808

quickly when it is accomplished with a pronoun rather than a name, even when the coreferential expression is part of a possessive NP. When an antecedent expression is the possessor in a possessive expression, there is no difference in the ease of comprehending a subsequent coreferential expression as a function of the form of the referring expression. This pattern of results is broadly similar to what was observed for conjoined NPs in Experiments 1a and 1b, and is consistent with the notion that discourse prominence, based on the syntactic status of the phrase that introduces an entity, has a significant effect on whether there is an advantage for subsequent coreference involving pronouns as compared to coreference involving names.

## EXPERIMENT 5

The goal of this experiment is to determine which participant in a possessive expression is most easily the object of subsequent reference with a pronoun. It does so using passages such as the ones illustrated in Table 11. According to our model (Gordon & Hendrick, 1998), the entity referred to by an entire complex NP should be more prominent in the discourse model than the entity referred to by a component NP; in this case that means subsequent reference to the possessed entity should be easier than subsequent reference to the possessing entity.

In contrast, both the advantage of first mention (Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989) and the complex NP assumption (Walker & Prince, 1996) lead to the expectation that the possessing entity (mentioned first) should be more accessible than the possessed entity (mentioned second). In fact, Walker and Prince (1996) use a possessive NP to illustrate the complex NP assumption, arguing that the possessor is more prominent than the possessed. Experiments 2 and 3 on conjoined NPs provided support for the alternative prediction of our model (Gordon & Hendrick, 1998) that the subject NP should be more prominent than its components. The current experiment examines which prediction is correct in the case of complex antecedent NPs that are possessives.

TABLE 11

Sample Passages Used in Experiment 5. The Critical Second Frame is Boxed

<p>Bill's aunt owns a lake house            where <b>she/he</b> likes to go swimming.</p>	<p>Bill's aunt owns a lake house.  <b>She/He</b> likes to go swimming there.</p>
<p>It's nice to live beside a lake.</p>	<p>It's nice to live beside a lake.</p>

## Method

*Subjects.* Eighty students at the University of North Carolina served as subjects. They received course credit in Introductory Psychology for their participation. None of the subjects had participated in the previous experiments.

*Stimulus Materials, Design and Procedure.* The experimental conditions are illustrated in Table 11. The second clause (or sentence) of each passage contained a pronoun that matched the gender either of the possessing entity or the possessed entity. The two were always of different genders. The factor of pronoun agreement was manipulated within subjects. The factor of within-sentence versus between-sentence coreference was manipulated between subjects. Otherwise, the stimuli, design and procedure were the same as in the previous experiments.

## Results

Table 12 shows the mean reading time for the critical frame consisting of the second clause or sentence. Outliers were excluded according to the same criteria used in the previous experiments; 0.78% of the observations were treated in this way. Reading times were lower when they contained pronouns that agreed in gender with the possessed entity than when they agreed in gender with the possessing entity [ $F_1(1,78) = 6.14, P < .02$ ;  $F_2(1,78) = 4.11, P < .05$ ]. The interaction of agreement and within/between sentence coreference was significant by subjects but not by items [ $F_1(1,78) = 5.57, P < .025$ ;  $F_2(1,78) < 1$ ].

## Discussion

The results of the experiment provide clear support for the hypothesis (Gordon & Hendrick, 1998) that the entity introduced by the complex NP is more prominent and accessible than its component entities. Reading times were faster for clauses containing a pronoun that agreed in gender with the possessed entity than with the possessing entity. These results are

TABLE 12  
Mean Reading Time (msec) for Critical Sentence  
in Experiment 5

	<i>Possessor</i>	<i>Possessed</i>
Within Sentence	1962	1879
Between Sentences	1797	1742

not what would be expected if the advantage of first mention, demonstrated in probe word recognition tasks (Gernsbacher & Hargreaves, 1988; Gernsbacher et al., 1989), is related to ease of subsequent reference; reference to the first mentioned participant (i.e. the possessing entity) would have been expected to be more easily understood. Further, the results are not consistent with the work hypothesis of Walker and Prince (1996) that ordering of prominence within a complex NP is from left to right.

## GENERAL DISCUSSION

The experiments in this paper examined how the structure of sentences and discourse interact with the linguistic form of referring expressions to influence the ease with which readers understand language. The results showed that a repeated-name penalty (slower reading of portions of text containing repeated names rather than pronouns; Gordon et al., 1993) was observed when reference was made to the entity introduced by the subject noun phrase of the first clause of a sentence. This effect was found regardless of whether or not the second referential expression was embedded in a complex NP consisting of conjoined NP or a possessive. In contrast, no repeated-name penalty was observed for reference to a component of the collective entity introduced by a conjoined NP that was the subject of the noun phrase of the first clause of a sentence. Nor was a repeated-name penalty observed for reference to the possessor in a possessive noun phrase. For both conjoined NPs and possessive NPs, reference to the entity introduced by the entire subject NP yielded the lowest reading times, a finding that is observed both for within-sentence and between-sentence coreference. In the following, the implications of these results are discussed with respect to two issues: (1) reference with names and pronouns, and (2) the effects of syntactic structure and sequential structure on the establishment of coreference.

### Reference with Names and Pronouns

Differences between the processes involved in comprehending names and pronouns have prompted a good deal of thought, some of which conflicts with the ideas presented in the current paper. Gernsbacher (1989) has argued that repeated names are comprehended more readily than pronouns because repeated names provide more information that can activate appropriate memory representations than do pronouns. She has supported this conclusion with the results of probe word reaction time studies that showed that pronominal reference to a previously mentioned character did not facilitate responses to a probe word consisting of that character's name, whereas repeated-name reference did facilitate re-

sponses. This view of the relation between processes of pronoun comprehension and name comprehension is at odds with the present view that pronouns are the natural and primary form for coreference, and that they are generally interpreted quite readily.

Gernsbacher's (1989) theoretical argument is an appealing one. Compared to a pronoun, an anaphoric name provides a great deal of information about both its antecedent and its referent. Indeed, in experimental studies the anaphoric name usually matches its antecedent exactly. Given the common assumption that memory representations are activated by matching inputs, the orthographic or phonological form of the anaphoric name would be a strong source of activation for the representation of the antecedent name. In contrast, a pronoun could only activate such a memory representation through connections based on matches on derived semantic dimensions such as gender, number and animacy. Thus, Gernsbacher (1989) argues that well-established principles about the operation of memory lead to the expectation that anaphoric names would be comprehended more readily than pronouns. In our view, well-established principles from the study of natural language semantics suggest the opposite.

A major goal in the development of model-theoretical semantics (Montague, 1974) was to extend the idea of meaning as truth-conditional interpretation to natural language. The construct of a model of discourse is crucial to this goal because the model provides the domain in which to evaluate the truth of an utterance. That is, the truth of an utterance can be evaluated with respect to the specific entities and relations that are represented in the model. According to Kamp and Reyle (1993), each successive utterance in a discourse adds to the model and in doing so elaborates on what the model presupposes for the interpretation of subsequent utterances. In this framework, anaphoric expressions involve reference to entities or propositions that are presupposed in the model, whereas nonanaphoric expressions introduce entities from general knowledge or the world into the model. From this perspective, interpreting pronouns is simpler than interpreting anaphoric names, because a pronoun must be interpreted anaphorically whereas the name could be anaphoric or not.<sup>2</sup> Accordingly, names are afflicted with a type of ambiguity that pronouns do not have. When we read the name "John" it could, in principle, refer to the John that we have just read about or to any other John we know.

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<sup>2</sup>This characterisation does not apply to deictic pronouns that directly refer to the world. The use of such pronouns depends on the speaker's ability to focus the hearer's attention on something in the world. Accordingly, deictic pronouns play little role in the comprehension of written narratives such as those studied in the current paper.

Empirical evidence suggesting that anaphoric names are interpreted more easily than pronouns comes from dual-task methodology in which subjects must respond to probe words while engaged in sentence comprehension. Gernsbacher (1989) found that repeated-name anaphors caused an immediate reduction in the response time to indicate that a probe name had occurred in the sentence being read, but pronouns caused no such reduction. Whereas Gernsbacher (1989) interpreted this as evidence that repeated-name anaphors are interpreted more easily than pronouns, others (Garrod, Freudenthal & Boyle, 1994; Gordon et al., 1993) have argued that this result may actually reflect the relationship between the anaphoric expression and the probe word, not the relationship between the anaphoric expression and the antecedent expression. Probe studies that do not use the repeated name itself as a probe have found that pronouns activate conceptual information associated with the entities to which they refer more rapidly than do repeated definite noun phrase anaphors (Cloitre & Bever, 1988). Further, the results of reading time experiments have consistently shown that sentences containing pronouns are read more rapidly than matched sentences containing repeated names when the pronoun or name is in a syntactically important position and can be interpreted as coreferential with an entity that was mentioned in a syntactically prominent position in the preceding sentence (Gordon & Chan, 1995; Gordon et al., 1993; Gordon & Scearce, 1995; Kennison & Gordon, 1997). We have interpreted this repeated-name penalty as indicating that pronouns are interpreted more easily than repeated names. An alternative interpretation, that pronouns are read more quickly than names because they are on average shorter and more frequent, is not plausible. The repeated-name penalty does not occur in all syntactic roles (Gordon et al., 1993), is reversed for entities in syntactic roles that are unusual (Gordon & Chan, 1995), and is not localised in the time to read the actual name or pronoun (Gordon & Scearce, 1995; Kennison & Gordon, 1997). These findings would not be expected if a general difference between names and pronouns caused the repeated-name penalty. A second alternative explanation, that pronouns are not usually interpreted at all (Greene, McKoon, & Ratcliff, 1992), cannot account for the observation of garden-pathing effects due to incorrect initial interpretation of pronouns (Gordon & Scearce, 1995), nor can it account for the differential ease of understanding different pronouns in the present experiments. Thus, the most straightforward account of the repeated-name penalty is that it indicates circumstances in which the interpretation of a sentence is easier when it contains a pronoun rather than a name. This is one of the basic phenomena addressed by our model of the processing of referential expressions (Gordon & Hendrick, 1997, 1998).

## Syntactic and Sequential Structure

In our model, the constituent structure of a sentence delimits the phrases that have reference and therefore is critical to introducing entities into the discourse model. The effect of constituent structure on how entities are represented in the discourse model leads to the predictions about the ease with which subsequent coreference is established by different types of referring expressions. Those predictions were supported by the results of the current experiments.

Our emphasis on constituent structure assigns a greater role to the hierarchical structure of language in these cases than it does to the sequential structure of language, a position that conflicts with that of researchers who assign a greater role to sequence of mention (Gernsbacher, 1990; Walker & Prince, 1996). The position taken by Gernsbacher and her colleagues is supported by a large number of probe word experiments. As in the case of the contrast between repeated names and pronouns, we believe that the results of the probe word task may reflect processes that are not normally involved in language comprehension.

A substantial body of research shows that memory for lists exhibits serial position effects. Current research on this topic by Neath (1993a,b; Neath & Knoedler, 1994) builds on work by Murdock (1960) in support of the idea that serial position effects result from the temporal distinctiveness of items. This notion was originally developed for the accuracy of memory for nonverbal materials (Neath, 1993a,b; Neath & Knoedler, 1994) but was extended by Neath and Knoedler (1994) to response times in the probe word recognition task. Neath and Knoedler (1994) argue that their quantitative model based on temporal distinctiveness is able to account for the great majority of findings that have been reported on the advantage of first mention. In particular, first mentioned participants derive temporal distinctiveness by occurring early in the presentation of a sentence. Second mentioned participants lose whatever temporal distinctiveness they might have due to recency because of the time that elapses between their occurrence and the presentation of the probe word. Neath and Knoedler (1994) argue that results on first mention using the probe word recognition task can be given a completely nonlinguistic explanation without recourse to concepts such as structure building (Gernsbacher, 1990, 1996). Whether or not the exact explanation offered by Neath and Knoedler (1994) is correct, it is clear that probe word recognition and reading time give very different views of the manner in which coreference is achieved. Understanding why this occurs is an important goal in arriving at appropriate methodological tools for studying language comprehension.

Although our model does assign an important role to syntactic structure in influencing coreference, it does not go as far as the binding theory



(Chomsky, 1981; Reinhart, 1976) in providing a completely hierarchical account of the conditions under which coreference with different forms of expressions is acceptable. Based on our studies on grammatical coreference (Gordon & Hendrick, 1997), we assign an important role to the sequencing of the major constituents of a sentence, although not of the words within those constituents. This allows our model to use the same incremental processing mechanisms for establishing coreference both within sentences and between them.

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