



## Effects of noun phrase type on sentence complexity<sup>☆</sup>

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### Abstract

A series of self-paced reading time experiments was performed to assess how characteristics of noun phrases (NPs) contribute to the difference in processing difficulty between object- and subject-extracted relative clauses. Structural semantic characteristics of the NP in the embedded clause (definite vs. indefinite and definite vs. generic) did not influence the magnitude of the processing difficulty even though corpus analysis showed a strong association between these NP classes and type of relative clause. Richness of lexical semantic content in a descriptive NP also had no influence on processing difficulty. However, the difference in processing difficulty was significantly reduced when a quantified pronoun appeared as the NP in the embedded clause. Together with previous findings, these results support the conclusion that NPs with common nouns differ in representational similarity from NPs consisting of proper names and pronouns, and that similarity in the memory representation of NPs contributes to the difficulty of processing syntactically complex sentences.

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Evidence about the nature of the information processing that underlies language comprehension can be obtained by having people read challenging sentences that disrupt the normally smooth process of language comprehension. Two types of challenging sentences have played prominent roles in this type of psycholinguistic research. The first is sentences with structural ambiguities (either local or global) where the timecourse of parsing and reanalysis can sometimes be discerned (e.g., Frazier & Rayner, 1982). The second is sentences that have little or no structural ambiguity but nevertheless are syntactically complex; such sentences can reveal

information about the moment-by-moment resource demands that during language comprehension (e.g., Wanner & Maratsos, 1978). This paper examines this latter type of sentence, aiming to advance understanding of how sentence complexity depends on the types of noun phrases (NPs) in a sentence (Bever, 1974; Gibson, 1998; Gordon, Hendrick, & Johnson, 2001). Understanding this dependency may provide insight into the types of representations that are present in working memory during syntactic processing.

The most notorious kind of syntactic complexity occurs in doubly center-embedded sentences (e.g., 1), which, though arguably grammatical, are usually impossible to understand (Miller & Chomsky, 1963).

1 The reporter the politician the commentator met trusts said the president won't resign.

Bever (1974) observed that, with respect to intuitive judgments, the acceptability of such sentences improves substantially when they contain a mixture of different types of NPs (e.g., 2).

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2 The reporter everyone I met trusts said that the president won't resign.

We have recently examined how the type of NPs in a sentence influence its complexity using the performance measures of reading time and comprehension accuracy (Gordon et al., 2001). Our investigation focused on the contrast between object-extracted (e.g., 3a) and subject-extracted (e.g., 3b) relative clauses (RCs).

3a The salesman that the accountant contacted spoke very quickly.

3b The salesman that contacted the accountant spoke very quickly.

It has been shown by a variety of measures that object-extracted RCs are more difficult to understand than subject-extracted RCs even though the sentences can be set up to have exactly the same words, only in a different order (Caramazza & Zurif, 1976; King & Just, 1991; MacWhinney, 1982; Wanner & Maratsos, 1978). Our results (Gordon et al., 2001) with this type of sentence showed elevated reading times and lower comprehension accuracy when the second NP (the NP in the embedded clause) was a definite description (as shown in 3a and 3b). However, this object–subject difference in processing difficulty was significantly reduced (or eliminated) when the second NP was the second-person pronoun (you) or a proper name (as shown in the contrasts between 4a and 4b).<sup>1</sup>

4a The salesman that you/Bob contacted spoke very quickly.

4b The salesman that contacted you/Bob spoke very quickly.

Warren and Gibson (2002) have also examined how the characteristics of animate NPs affect the complexity of multi-clause sentences. Using ease-of-understanding ratings and self-paced reading time, they found systematic effects of the type of NP on the complexity of center-embedded sentences. We will consider two types of explanations for the effects of types of NPs on sentence complexity as observed by Gordon et al. (2001) and Warren and Gibson (2002): one that focuses on properties of the critical NP within the embedded clause (henceforth NP2) and a second that focuses on the in-

teraction between the NP within the embedded clause with other NPs in the sentence.

The dependency locality theory (DLT), proposed by Gibson (1998), explains NP effects on sentence complexity in terms of properties of the NP in the embedded clause. This theory states that the processing cost of integrating structures in a sentence increases with the distance over which the integration occurs. Most crucially, the theory states that the integration cost increases with the number of new discourse referents that are introduced between the phrasal heads that must be integrated. Indexical pronouns (like “you” in example 4) are said not to introduce new discourse referents because the referent is implicit in the discourse environment, thereby causing the reduction in the doubly embedded structures (Bever, 1974) and the reduction in the object–subject difference with the pronoun “you” (Gordon et al., 2001). The theory depends crucially on this notion of the givenness of a discourse referent as formulated in the Gundel, Hedberg, and Zacarski (1993) *Givenness Hierarchy*. Warren and Gibson (2002) argue that an NP that is high on the Givenness Hierarchy is “central” to the discourse and therefore is highly activated and accessible for processing. In contrast, an NP that is low on the Givenness Hierarchy is “peripheral” to the discourse and therefore relatively inaccessible in the sense that it must be retrieved from long-term memory. These ideas are systematically tested by Warren and Gibson (2002). While dependency locality theory focuses on the discourse status of the embedded NP, the experiments in Warren and Gibson (2002) examine single sentences isolated from discourse context.

An alternative, which also focuses on the characteristics of the embedded NP, is to explain the object–subject difference (e.g., 4a vs. 4b) as based on the fact that, in object-extracted RCs, the embedded NP is the subject of the relative clause while in subject-extracted RCs it is the object of the relative clause. Thus, the reduction of the object–subject difference might be expected with sentences where NP2 is commonly a subject. A substantial literature indicates that grammatical subjects tend to have certain properties, even though it is possible for an expression to be a subject without those properties. In particular, grammatical subjects tend to be definite NPs that refer to human entities that tend to be pronominal. Thus, the effect of indexical pronouns in reducing the object–subject difference could be due to the fact that pronouns are very good subjects—“prototypical” subjects in the terminology of cognitive psychology and “unmarked subjects” in the terminology of linguistics. The extent to which NP2 has the properties commonly associated with subjects is unlikely to provide a complete account of how types of NPs resulted in a reduction of the object–subject difference in the experiments of Gordon et al. (2001). Substantial object–subject differences were observed when the second NP was a

<sup>1</sup> It should be noted that this effect was observed in a situation where both of the critical NPs were animate. Recent work (Mak, Vonk, & Schriefers, 2002; Traxler, Morris, & Seely, 2002) have shown that the animacy of the critical NPs can influence the magnitude of the object–subject difference in ease of processing. As Mak et al. (2002) observe this points to the need to incorporate some notions of semantically driven analysis in models of sentence processing, an observation also present in King and Just (1991), who manipulated the degree of association between the critical NPs and the verbs in the relative clause. This idea does not conflict with the ones that we develop here.

description while none was observed when it was the second-person pronoun or was a proper name. All of these are definite NPs that refer to humans and hence have a property commonly associated with subjects. This notion is supported by corpus research (Fox & Thompson, 1990; Gordon & Hendrick, *ms*) that indicates that the second NPs in object-extracted expressions tend to have the characteristics typically observed of grammatical subjects, and also by evidence that the object–subject difference in RCs is reduced when NP2 is animate (a characteristic of good subjects) as compared to when it is inanimate (Traxler et al., 2002).

The second possible explanation focuses on the similarity between the two critical NPs in the sentence. The parsing of relative clauses has traditionally been assumed to require that intermediate representations be stored and accessed in working memory, with object-extracted RCs imposing a greater memory load than subject-extracted RCs. Memory interference during encoding and/or retrieval may occur when the two NPs are similar, with the magnitude of that interference interacting with the memory load imposed by the type of sentence structure; this leads to the dependency of syntactic complexity on the types of NPs in the sentence. Lewis (1996, 1999) proposed a model of sentence comprehension based on the concept of memory interference during reading. However, as opposed to more standard psychological approaches to memory interference, Lewis suggests that syntactic dependencies are the types of information upon which memory interference operates. Connectionist accounts of sentence processing could also be seen as suggesting that similarity between NPs could lead to processing difficulty with complex sentences. For example, the model developed by MacDonald and Christiansen (2002) operates solely in terms of the propagation of activation through weighted connections between words without separate storage of intermediate representations. While their model does not have an implementation of word (or NP) similarity, related connectionist models (Rumelhart & McClelland, 1986) frequently implement similarity through overlapping patterns of connection strengths. In the case of sentence processing, these overlapping connections for similar NPs could naturally be seen as a source of similarity-based interference in processing.

Two lines of experimental evidence indicate that the similarity of NPs contributes to sentence-complexity effects. First, Gordon et al. (2001) used object- and subject-extracted cleft sentences that contained NPs of either matched type (two names or two descriptions) or unmatched type (a name and a description). They found that the object–subject difference was greater with NPs of matched type than unmatched type, suggesting that similarity of the NPs plays an important role. Second, Gordon, Hendrick, and Levine (2002) found that the match between type of words in a memory load and type

of NPs in a sentence also affected the object–subject difference. A greater object–subject difference in sentence comprehension was observed when the words in the concurrent memory load matched those in the critical NPs of the sentence (both names or both descriptions) than when they did not match. As with the reading time data on clefts, this pattern shows that the similarity between NPs (or the words of which they are composed) is a critical factor in determining how syntactic complexity depends on the types of NPs in a sentence.

The two factors discussed above, characteristics of the embedded NP and similarity of the critical NPs, point to quite different origins in processing for this type of sentence-complexity effect. A strong influence of the first factor raises the need to distinguish between an approach, like Gibson's, that emphasizes the memory impact of discourse referents as compared to a more local explanation that there is a bias for interpreting NPs with prototypical subject characteristics as the subjects of verbs. The facilitative effect of such a bias could be substantial during the comprehension of object-extracted RCs because the normal word-order cues to parsing are not present in object-extracted RCs which deviate from canonical word ordering. In the absence of those cues, the bias for interpreting NPs that are prototypical subjects as subjects becomes an important factor in facilitating comprehension. A strong influence of the second factor (similarity of the critical NPs in the sentence) suggests a focus on how NPs are represented and retrieved in working memory during sentence processing. Understanding object-extracted RCs requires that both critical NPs be stored in memory before either is integrated with a verb. This means that the correct NP must be retrieved from memory to perform the integration, a process that could be impaired by interference when the NPs are similar. In subject-extracted RCs, the first NP can be integrated with the first verb before the second NP is read, thereby reducing the susceptibility of memory retrieval to this type of interference. Thus, these two factors—a second NP with characteristics common to subjects and similarity of the critical NPs—suggest different types of mechanisms as critical to the processing difficulty encountered in complex sentences. It is important to note that the two types of mechanisms are not incompatible and that both could contribute to language processing.

The present experiments use self-paced reading to explore systematically how the characteristics of the embedded NP (NP2) and the similarity of the critical NPs in a sentence modulate the object–subject difference in understanding relative clauses. The characteristics of NP2 are manipulated so as to make them more or less common as measured by the statistical frequency of different NP characteristics as NP2 in relative clauses. The statistical frequencies of NP characteristics in object vs. subject RCs, when possible, were determined via

corpus analyses. In addition, the experiments manipulate the similarity of the critical NPs in the sentence so as to determine whether specific NP characteristics contribute to similarity-based interference. Four experiments following this general strategy examine the contribution of NP characteristics at a number of levels of language analysis.

### Experiment 1

This experiment manipulates whether NP2 is definite or indefinite, a straightforward manipulation that involves using either a definite article (the) or an indefinite article (a or an) as illustrated in 5a and 5b.

5a The salesman that *thelan* accountant contacted spoke very quickly.

5b The salesman that contacted *thelan* accountant spoke very quickly.

Definite expressions are widely considered to be more prototypical than indefinite expressions as sentential (or clausal) subjects (Givón, 1984). While couched in a variety of ways, the fundamental reason for this belief is that subjects are used to refer to given information, a function that can be achieved with definite expressions but not with indefinite expressions. In the Givenness Hierarchy of Gundel et al. (1993), as employed by Warren and Gibson (2002), indefinite NPs are more peripheral while definite NPs are more central. Thus, the object–subject difference should be smaller with a definite NP2 than with an indefinite NP2 if either prototypicality-as-a-subject or discourse centrality facilitates the comprehension of object extractions. Two experiments in Warren and Gibson (2002), one involving ratings of ease of understanding and the second involving self-paced reading, provide some evidence in support of this idea.

With respect to an account of the object–subject difference based on the similarity of the critical NPs, the design used in this experiment leads to the prediction that the difference would be larger with a definite NP than with an indefinite NP since the critical NPs are more similar when both are definite. Of course, that prediction assumes that definiteness is a relevant psychological dimension for similarity-based interference in memory retrieval.

### Method

#### Corpus analysis

Information about the frequency with which NP2 was definite or indefinite was extracted from a large-scale study that we have conducted on the characteristics of NPs in RCs. Samples of RCs were randomly selected from three corpora, the Brown Corpus (Kučera & Francis, 1967), Switchboard (Godfrey, Holliman,

& McDaniel, 1992), and Chiles (MacWhinney, 2000). These corpora differ substantially from one another. Brown and Switchboard consist of language produced by adults; Chiles contains language produced by children and adults, though we only analyzed language by children (ages 3–5 years). Brown contains written language in a variety of different genres. Switchboard contains phone conversations on assigned topics between adults who do not know each other. Chiles contains naturally occurring face-to-face conversations involving children. Trained judges coded the NPs from the RCs in the sampled sentences. Definite NPs were defined by employing the well-known restriction that such NPs are excluded from appearing in existential constructions (i.e., after the verb be in strings such as there is/are \_\_\_\_ in the room). Only indefinites appear freely in this construction. If an NP could appear in an existential construction it was classed as definite; otherwise it was considered indefinite. Independent coding of randomly selected subsamples was used to establish reliability according to a criterion of  $\kappa > .8$  (Carletta, 1996; Siegel & Castellan, 1988) for all pairs of coders on all coding dimensions.

#### Participants

Forty-eight students at the University of North Carolina at Chapel Hill served as participants in the experiment. They received course credit in Introductory Psychology for their participation.

#### Stimulus materials

Stimuli for each run of the experiment consisted of 24 experimental sentences and 44 filler sentences. Other than changes to the NPs, the sentences were the same as those used in Gordon et al. (2001). The subject of the experimental sentences was always a singular, definite description relating to a human role (e.g., the dancer, the lawyer, the banker, etc.). These sentences also each contained a relative clause that modified the subject NP of the main clause. The embedded NP of the RC was a singular description of a human role, but the description was either a definite one or an indefinite one (e.g., a doctor, a mailman, a comedian, etc.). Half the RCs were subject extracted and the other half were object extracted. Thus, each participant was presented with six sentences in each of four conditions defined by the combination of type of relative clause (subject vs. object extracted) and type of embedded NP (definite description vs. indefinite description). The stimuli are shown in the Appendix. In order to ensure that our stimuli were not biased in terms of plausibility (i.e., it is not more likely that the agent of the RC would be performing the actions described by the embedded and matrix verbs than the patient of the RC), we had 24 separate participants rate the plausibility of our stimuli in either the original form (e.g., The architect that the fireman liked

dominated the conversation while the game was on television) or in a reversed form (The fireman that the architect liked dominated the conversation while the game was on television). The reversed form stimuli were created by switching the position of the agents and patients of the RC in the subject-extracted version of the sentence. Participants rated the plausibility of these sentences by reading them in a questionnaire and rating plausibility on a 9 point Likert scale. An analysis of variance of their ratings of the original stimuli vs. the reversed form stimuli revealed that participants found no difference in plausibility between the original (mean rating of 5.53) and reversed form (mean rating of 5.64) stimuli;  $F_1(1, 23) = .24$ ,  $MSE = 7.44$ ,  $p > .6$ ,  $F_2(1, 23) = .34$ ,  $MSE = 5.30$ ,  $p > .55$ . Thus, we concluded that the lack of bias in our sentence precluded any potential confounding effect such bias could cause. Assignment of individual sentences to experimental conditions was counterbalanced across participants, so that across participants each sentence was presented in each of the four conditions. Eight of the sentence designs were taken from Appendix 2 of King and Just (1991) and the remaining 16 sentence designs were created by Gordon et al. (2001). The 44 filler sentences conveyed complex ideas but did not contain restrictive relative clauses.

#### Design and procedure

An experimental run consisted of four blocks of sentences. The first block contained 14 filler sentences. Each subsequent block contained 10 filler sentences and eight experimental sentences. These three blocks had an equal number of sentences in each of the four conditions (object extracted vs. subject extracted by definite NP2 vs. indefinite NP2). The order of sentence presentation was randomized within blocks. A participant only saw each experimental sentence as one of the four conditions; across participants every sentence occurred in each of the four conditions.

On each trial, the sentence was presented to the participant one word at a time in the center of a computer screen. Participants pressed the spacebar to proceed to

the next word of the sentence. They were instructed to read the sentence at a natural pace, not to hurry but not to linger longer than necessary before pressing the spacebar to see the next word. After each sentence a comprehension question was presented to the participant. Each question asked whether a statement was true or false. Half the answers were true and half were false. Correct answers for the experimental sentences required an understanding of the syntactic/semantic relations between the main and embedded NPs and the matrix verb or verb in the embedded clause. One-third of the questions referred to the matrix verb and two-thirds referred to the verb in the embedded clause. Correct answers for the filler sentences required an understanding of the complex idea conveyed in the sentence.

#### Results

Table 1 shows the frequency of RCs by type of extraction (subject vs. object) and by type of NP2 (definite vs. indefinite) for the Brown, Childe, and Switchboard samples. It should be noted that this analysis only includes cases where there is a transitive verb in the embedded clause, since there is no NP2 when the embedded verb is intransitive. Further, since intransitive verbs cannot have object extractions, eliminating sentences with intransitive verbs reduces the number of subject extractions but does not affect the number of object extractions. When RCs with embedded intransitive verbs are included in the totals, then all three corpora show more subject extractions than object extractions, though this pattern is less pronounced for Switchboard as compared to the other two corpora.

A highly significant association between these two factors was observed for each corpus, wherein there was a lower incidence of object-extracted RCs with indefinite NP2s than would be expected by chance if the two factors were independent; Brown ( $\chi^2 = 96.1$ ,  $p < .001$ ), Childe ( $\chi^2 = 43.5$ ,  $p < .001$ ), and Switchboard ( $\chi^2 = 84.3$ ,  $p < .001$ ). Table 1 also shows this same information for sentences where the modified NP was definite.

Table 1  
Counts from three corpora of RCs by type of extraction and characteristics of NP2 (the first NP in the embedded clause)

	Brown		Childe		Switchboard	
	Subject	Object	Subject	Object	Subject	Object
Definite	845	772	202	241	195	378
	450	474	114	129	78	195
	279	305	97	93	49	122
Indefinite	157	15	43	1	57	3
	70	12	11	0	14	0
	60	6	9	0	10	0

The first row within each cell gives the frequency count overall. The second row gives the frequency count for instances where NP1 was definite. The third row gives the frequency count where NP1 was both definite and singular.

That condition is of interest because the modified NPs were definite in our experimental stimuli. The pattern of association between definiteness of NP2 and type of extraction for this subsample of the corpus was the same as the pattern overall; Brown ( $\chi^2 = 40.5$ ,  $p < .001$ ), Childes ( $\chi^2 = 11.9$ ,  $p < .005$ ), and Switchboard ( $\chi^2 = 31.2$ ,  $p < .001$ ). Finally Table 1 shows this breakdown for sentences where the modified NP was both definite and singular, providing an even closer approximation to our stimuli. The pattern of association between definiteness of NP2 and type of extraction for this subsample of the corpus was also the same as the pattern overall; Brown ( $\chi^2 = 42.2$ ,  $p < .001$ ), Childes ( $\chi^2 = 8.3$ ,  $p < .005$ ), and Switchboard ( $\chi^2 = 21.9$ ,  $p < .001$ ).

Table 2 shows the mean reading times for sentences in each of the four experimental conditions. Analyses of variance, by participants ( $F_1$ ) and items ( $F_2$ ), were performed on the mean reading times for two critical words in the sentence and on the accuracy in response to the comprehension questions. For subject-extracted RCs, the first critical word was the head of the embedded NP (the logical object of the RC). For object-extracted RCs, the first critical word was the verb of the embedded clause. The second critical word for both subject-extracted and object-extracted RCs was the verb of the main clause. Previous work (Gordon et al., 2001; King & Just, 1991) has established that these two words are the principal loci of reading time differences for sentences with RCs that restrict the subject. Reading times for the first critical word were significantly slower in object-extracted RCs than subject-extracted RCs;  $F_1(1, 47) = 16.05$ ,  $MSE = 225, 389$ ,  $p < .001$ ,  $F_2(1, 23) = 12.88$ ,  $MSE = 140, 436$ ,  $p < .005$ . There was no signifi-

cant difference in the first-critical-word reading times for the different forms of the embedded NP;  $F_1(1, 47) = .27$ ,  $MSE = 194, 623$ ,  $p > .6$ ,  $F_2(1, 23) = .19$ ,  $MSE = 136, 328$ ,  $p > .65$ . There also was no significant interaction between clause type and form of embedded NP for the first critical reading times;  $F_1(1, 47) = .06$ ,  $MSE = 72, 644$ ,  $p > .8$ ,  $F_2(1, 23) = .01$ ,  $MSE = 176, 883$ ,  $p > .9$ . Times for the second critical word followed the same pattern as the first critical word. Object-extracted RCs were read significantly slower than subject-extracted RCs;  $F_1(1, 47) = 13.53$ ,  $MSE = 213, 752$ ,  $p < .005$ ,  $F_2(1, 23) = 8.47$ ,  $MSE = 170, 804$ ,  $p < .01$ , but the form of the embedded NP had no effect on reading times;  $F_1(1, 47) = 1.33$ ,  $MSE = 178, 732$ ,  $p > .25$ ,  $F_2(1, 23) = 1.44$ ,  $MSE = 82, 475$ ,  $p > .2$ , and there was no significant interaction between clause type and form of embedded NP;  $F_1(1, 47) = .35$ ,  $MSE = 98, 997$ ,  $p > .55$ ,  $F_2(1, 23) = .14$ ,  $MSE = 119, 867$ ,  $p > .7$ .

While the second critical word is the same for both types of clauses, the first critical word differs; it is a verb for an object RC and a noun for a subject RC. In order to reduce potential problems from the comparison for the text region of the first critical word, an analysis of variance was performed on a control region defined as the mean of the reading times of the embedded NP, its article, and the embedded verb. This comparison involves exactly the same words only in a different order. It showed a significant difference between object and subject relative clauses where the noun and verb of object relative clauses were read more slowly than the verb and noun of subject relative clauses;  $F_1(1, 47) = 10.60$ ,  $MSE = 30, 583$ ,  $p < .005$ ,  $F_2(1, 23) = 4.63$ ,  $MSE = 34, 971$ ,  $p < .05$ . No difference was found on this mea-

Table 2  
Reading time results (ms) for Experiment 1

	Sentence Beginning (Before Critical Words)	Control Region RC after "that"	Critical 1 Embedded Verb or NP2	Critical 2 Main Verb	Sentence Remainder	Accuracy on Question
Object-Definite	469	632	967	1008	563	84
	The salesman that the accountant	the accountant contacted	contacted	spoke	very quickly	
Subject-Definite	463	555	702	736	518	95
	The salesman that contacted the	contacted the accountant	accountant	spoke	very quickly	
Object-Indefinite	458	629	943	911	599	85
	The salesman that an accountant	an accountant contacted	contacted	spoke	very quickly	
Subject-Indefinite	471	541	660	693	515	90
	The salesman that contacted an	contacted an accountant	accountant	spoke	very quickly	

The average reading time per word is shown for various sentence regions as a function of type RC extraction and type of NP2. The text for each condition is presented beneath the reading time. Percent correct on answering the comprehension question for each of the conditions is also given.

sure for second NP type;  $F_1(1, 47) = .12$ ,  $MSE = 29,060$ ,  $p > .7$ ,  $F_2(1, 23) = .07$ ,  $MSE = 27,719$ ,  $p > .8$ , and the mean of the noun and verb did not significantly differ as a result of the interaction of clause type and second NP;  $F_1(1, 47) = .12$ ,  $MSE = 13,866$ ,  $p > .7$ ,  $F_2(1, 23) = .02$ ,  $MSE = 33,535$ ,  $p > .8$ .

Comprehension questions were answered more accurately for subject RCs (92.7%) than for object RCs (84.9%);  $F_1(1, 47) = 13.88$ ,  $MSE = 211.011$ ,  $p < .005$ ,  $F_2(1, 23) = 13.61$ ,  $MSE = 107.658$ ,  $p < .005$ . No effect of form of embedded NP was found for question accuracy;  $F_1(1, 47) = 1.03$ ,  $MSE = 169.148$ ,  $p > .3$ ,  $F_2(1, 23) = 1.18$ ,  $MSE = 73.942$ ,  $p > .25$ . Also, there was no interaction between clause type and form of embedded NP for question accuracy;  $F_1(1, 47) = 2.38$ ,  $MSE = 175.797$ ,  $p > .1$ ,  $F_2(1, 23) = 2.11$ ,  $MSE = 98.851$ ,  $p > .15$ .

To show that our finding of no interaction between the RC type and the definite/indefinite conditions was not due to a lack of statistical power, we conducted a power analysis using the results of the first critical word reading time. Using the error terms of the main effects and interaction of the ANOVA on this word, we found that we had power above .8 to detect an interaction of the size found in experiment 3 of Gordon et al. (2001) (this interaction was found when names replaced the embedded NP of the RC). Thus, we concluded that our lack of detection of an interaction between the two factors of our ANOVA was not due to a lack of statistical power.

### Discussion

The frequency counts showed that NP2 was much more likely to be definite than indefinite. In addition, they showed a strong, highly significant pattern of association between type of RC and whether NP2 was definite or indefinite, with subject extractions having a far greater incidence of indefinite NP2s than object extractions. This pattern was highly consistent across the three corpora that we investigated. The scarcity of indefinite NP2s in object extractions is consistent with the idea that indefinite NPs are relatively non-prototypical as the subject of a sentence or clause, perhaps because an indefinite form signals that its referent is peripheral to the current discourse model (Warren & Gibson, 2002). These corpus results strongly support linguistic characterizations of grammatical subjects vs. objects (Givón, 1984; Gundel et al., 1993) and are consistent with the psycholinguistic analyses presented by Warren and Gibson (2002).

The experiment showed a strong main effect of type of RC, with object-extracted RCs causing greater processing difficulty than subject-extracted RCs as indicated by comprehension accuracy and by several measures of reading time. The experiment provided no indication of an interaction between type of extraction and status

of NP2 suggesting that definiteness is not a powerful factor in the object–subject difference. This conclusion contrasts with Warren and Gibson's (2002) conclusion that the Givenness Hierarchy, including the definite–indefinite contrast, plays an important role in sentence-complexity effects. Differences between the present experiment and those of Warren and Gibson (2002) may explain the difference in effects that lead to these contrasting conclusions. Their first experiment looking at this effect used an off-line, ease-of-understanding rating but did not measure online sentence comprehension performance. Further, statistical analysis of that experiment tested for a monotonically increasing trend across many levels of givenness; it did not include a focused contrast between definite and indefinite NPs. Their second experiment did measure online sentence comprehension performance. However, again no focused contrast was reported on the difference between definite and indefinite NPs in the statistical analyses. More importantly, the experiment only looked at object-extracted RCs; this means that any differences observed could simply be main effects of the type of NP on sentence comprehension, not an effect of NP type on sentence complexity. Our current experiment used online performance measures to provide a focused contrast of definite vs. indefinite, embedded NPs in an experimental design where the effect of type of NP on sentence complexity could be isolated from any possible main effects of NP type. While our analyses of off-line corpus data are consistent with the idea that indefinite embedded NPs in complex, object-extracted RCs are very uncommon, these focused online measures give no suggestion that the definite–indefinite contrast plays a role in sentence-complexity effects.

The experiment was also designed to test an elaboration of the similarity-based interference model presented in Gordon et al. (2001). Because the first NP was always definite, having an indefinite NP2 meant that the two NPs were dissimilar, which might have been expected to reduce similarity-based interference if similarity at this structural semantic level played a role in memory retrieval. The finding that the definiteness of NP2 had no impact on the object–subject difference suggests either that the similarity-based interference model is incorrect or that definiteness is not a relevant psychological dimension of similarity at the level of language processing measured by the object–subject difference.

It should be noted that the reading times in this experiment were longer than usual reading times in some self-paced reading and eye-tracking studies. This finding is not unexpected, in that participants were reading complex sentences in an experimental setting that did not allow regressive reading patterns. Thus, we would expect reading times of the magnitude found in this study, which were also observed in Gordon et al. (2001).

Moreover, as the power analyses indicate in this and in subsequent experiments, these high reading times should not be considered to be masking effects.

## Experiment 2

This experiment examines whether a second structural semantic characteristic of an NP, one which is related to its prototypicality as a subject and as an object, influences the processing difficulty associated with object-extracted RCs. It does so by manipulating whether NP2 is definite or generic, as shown in 6a and 6b.

6a The salesman that (*the accountants/accountants*) contacted spoke very quickly.

6b The salesman that contacted (*the accountants/accountants*) spoke very quickly.

In order to have the head of the NPs match across the conditions, we used plural nouns for the definite NPs rather than the singular nouns that we used for NP2 in the last experiment.

Examination of generics serves two purposes. First, in addition to being non-prototypical as subjects, generics are prototypical as objects, giving them two possible sources of influence in increasing the object–subject difference if association between NP type and syntactic role contributes to the magnitude of the complexity effect on comprehension. Generics are not situated within the Givenness Hierarchy either by Gundel et al. (1993) or by Warren and Gibson (2002). Warren and Gibson do speculate, however, that quantified expressions pattern as more ‘given’ in a discourse than definite descriptions. Semantic analyses suggest strongly that generics involve quantification in a discourse (cf., Krifka et al., 1995). Thus, generics provide some insight into how expressions of quantification influence the complexity of RC structure.

Second, in the previous experiment the definite/indefinite manipulation had no effect on performance. Corpus analysis showed that NP2 was more likely to be definite than indefinite and it also showed a strong association between definiteness in NP2 and type of extraction, which suggests that it is reasonable to expect definiteness to have an effect on performance. However, the absence of a main effect of definiteness suggests that the failure to find an interaction of definiteness and type of extraction may be due to a lack of potency in the definite/indefinite manipulation.

## Method

### Corpus analysis

Corpus analysis was conducted in the same way as in the previous experiment. Status as a generic was operationalized as a bare plural.

## Participants

Forty-eight students from the same population as the previous study participated in this experiment.

## Stimuli, design, and procedure

The 44 filler sentences that were used in the previous experiments were also used in this study. The experimental stimuli were modified from the previous experiments to produce four conditions also defined by two factors. Again, the first factor was type of relative clause (object vs. subject). The second factor was type of embedded NP. While the subject NP of the sentence was always a singular definite NP, the embedded NP was either a plural definite NP or a plural generic (e.g., secretaries, directors, painters, etc). The four experimental conditions were counterbalanced across participants as in the preceding experiments so that each sentence was presented in each of the four conditions. Each participant still received the same number of stimuli per experimental block, so each condition occurred twice per block. All other aspects of the design and procedure were maintained. Though the sentences in the generic conditions had no article in the RC, the critical words were still defined as the main verb of the sentence and either the embedded NP or the embedded verb.

## Results

Table 3 shows the frequency of RCs by type of extraction (subject vs. object) and by type of NP2 (definite vs. generic) for samples from the three corpora. A strong association between these two factors was observed for each corpus: Brown ( $\chi^2 = 166.2$ ,  $p < .001$ ), Childes ( $\chi^2 = 37.7$ ,  $p < .001$ ), and Switchboard ( $\chi^2 = 84.2$ ,  $p < .001$ ). In each case, the co-occurrence of object extraction with a generic NP2 was underrepresented. Table 2 also shows this same information for sentences where the modified NP was definite. The pattern of association between type of extraction and definite vs. generic for this subsample of the corpus was the same as the pattern overall: Brown ( $\chi^2 = 58.6$ ,  $p < .001$ ), Childes ( $\chi^2 = 9.2$ ,  $p < .005$ ), and Switchboard ( $\chi^2 = 41.1$ ,  $p < .001$ ). Finally Table 2 shows this breakdown for sentences where the modified NP was both definite and singular and where NP2 was plural, providing an even closer approximation to our stimuli. For the most part, the pattern of association between definiteness of NP2 and type of extraction for this subsample of the corpus was also the same as the pattern overall; Brown ( $\chi^2 = 8.6$ ,  $p < .005$ ), Childes ( $\chi^2 = 8.0$ ,  $p < .005$ ), and Switchboard ( $\chi^2 = 3.0$ ,  $p < .10$ ).

Table 4 shows the mean reading times for sentences in each of the four conditions. Object RCs were once again read slower than subject RCs both for the first critical word;  $F_1(1, 47) = 20.80$ ,  $MSE = 125,656$ ,  $p < .001$ ,  $F_2(1, 23) = 32.96$ ,  $MSE = 39,642$ ,  $p < .001$ ,



Table 3  
Counts from three corpora of RCs by type of extraction and characteristics of NP2 (the first NP in the embedded clause)

	Brown		Childes		Switchboard	
	Subject	Object	Subject	Object	Subject	Object
Definite	845	772	202	241	195	378
	450	474	114	129	78	195
	51	72	5	15	7	39
Generic	316	37	45	4	67	8
	116	23	11	1	14	0
	19	7	4	0	2	2

The first row within each cell gives the frequency count overall. The second row gives the frequency count for instances where NP1 was definite. The third row gives the frequency count where NP1 was both definite and singular while NP2 was plural.

Table 4  
Reading time results (ms) for Experiment 2

	Sentence Beginning (Before Critical Words)	Control Region RC after “that”	Critical 1 Embedded Verb or NP2	Critical 2 Main Verb	Sentence Remainder	Accuracy on Question
Object-Definite	527 The salesman that the accountants	682 the accountants contacted	996 contacted	850 spoke	664 very quickly	85
Subject-Definite	544 The salesman that contacted the	616 contacted the accountants	735 accountants	756 spoke	609 very quickly	86
Object-Generic	572 The salesman that accountants	839 accountants contacted	1008 contacted	975 spoke	671 very quickly	87
Subject-Generic	554 The salesman that contacted	702 contacted accountants	803 accountants	852 spoke	593 very quickly	88

The average reading time per word is shown for various sentence regions as a function of type RC extraction and type of NP2. The text for each condition is presented beneath the reading time. Percent correct on answering the comprehension question for each of the conditions is also given.

and for the second critical word;  $F_1(1, 47) = 9.25$ ,  $MSE = 60,793$ ,  $p < .005$ ,  $F_2(1, 23) = 8.55$ ,  $MSE = 32,893$ ,  $p < .01$ . No main effect of NP condition was found for the first critical reading time;  $F_1(1, 47) = .75$ ,  $MSE = 101,134$ ,  $p > .35$ ,  $F_2(1, 23) = .36$ ,  $MSE = 105,758$ ,  $p > .55$ , but the second critical word was read significantly faster in the plural condition than in the generic condition;  $F_1(1, 47) = 5.71$ ,  $MSE = 102,943$ ,  $p < .05$ ,  $F_2(1, 23) = 5.75$ ,  $MSE = 51,095$ ,  $p < .05$ . The mean reading times of the embedded NP and the embedded verb (the region designed to control for effects possibly due to word differences) showed the same pattern as the second critical word for RC type;  $F_1(1, 47) = .1508$ ,  $MSE = 32,594$ ,  $p < .001$ ,  $F_2(1, 23) = 14.07$ ,  $MSE = 17,467$ ,  $p < .005$ , and for second NP type;  $F_1(1, 47) = 24.57$ ,  $MSE = 28,892$ ,  $p < .001$ ,  $F_2(1, 23) = 9.31$ ,  $MSE = 38,143$ ,  $p < .01$ . Nevertheless, no significant interaction between RC type and embedded NP type was found for the first critical

reading time;  $F_1(1, 47) = .31$ ,  $MSE = 121,747$ ,  $p > .55$ ,  $F_2(1, 23) = .34$ ,  $MSE = 55,590$ ,  $p > .55$ , the second critical reading time;  $F_1(1, 47) = .16$ ,  $MSE = 60,109$ ,  $p > .65$ ,  $F_2(1, 23) = .07$ ,  $MSE = 75,040$ ,  $p > .75$ , or for the mean of the embedded NP and verb;  $F_1(1, 47) = 2.51$ ,  $MSE = 24,740$ ,  $p > .1$ ,  $F_2(1, 23) = 1.31$ ,  $MSE = 23,757$ ,  $p > .25$ .

Comprehension question accuracies did not differ significantly by RC type;  $F_1(1, 47) = .49$ ,  $MSE = 187.155$ ,  $p > .45$ ,  $F_2(1, 23) = .20$ ,  $MSE = 233.494$ ,  $p > .65$ , or by embedded NP type;  $F_1(1, 47) = 1.14$ ,  $MSE = 126.945$ ,  $p > .25$ ,  $F_2(1, 23) = 1.33$ ,  $MSE = 54.222$ ,  $p > .25$ . There also was no significant interaction between RC type and embedded NP type for comprehension question accuracy;  $F_1(1, 47) = 0$ ,  $MSE = 183.215$ ,  $p > .95$ ,  $F_2(1, 23) = 0$ ,  $MSE = 48.309$ ,  $p > .95$ .

We conducted a power analysis comparable to that of Experiment 1, except using the error terms from the

current experiment, to insure that the absence of an interaction in our data was not due to a lack of statistical power. Again, we found that we had power above .8, a level for which it is reasonable to conclude that we did have enough statistical power to detect an interaction between RC type and sentence form had one been present.

### Discussion

The frequency counts of the corpus analysis showed that NP2 was much more likely to be definite than generic, and that there was a significant pattern of association between type of RC and whether NP2 was definite or generic. Subject extractions had a far greater incidence of generic NP2s than did object extractions, a pattern that was consistent across three corpora. Overall, the differences in frequency observed between definite and generic NPs is very similar to those observed in the previous experiment for definite and indefinite NPs.

The results of the experimental manipulation showed the expected object–subject difference on reading times, with greater reading times shown for object-extracted RCs as compared to subject-extracted RCs on three measures of reading time, but did not show this difference on comprehension accuracy.

It should be noted that the test for a main effect of NP2 type for the control region (the mean reading times of the embedded NP and verb) may be influenced by a differing number of words in the two conditions (generics have one fewer word than definite descriptives). It is possible that the observed main effect of NP2 type could be due to this disparity. However, the main goal of this set of experiments is to detect the influence of NP types on object–subject differences. In this experiment we found a main effect of RC type for this control region, but, as in the last experiment, there was no interaction between type of RC and type of NP2 on any of the dependent measures. However, there was a main effect such that having a generic as NP2 significantly increased reading time on the matrix verb, which is matched across conditions. Thus, even though generic NPs affected comprehension, they did not do so selectively across types of RCs. No increase in the object–subject difference was observed because of the non-prototypicality of a generic NP as a subject, nor was a decrease in the object–subject difference observed because of the dissimilarity created by having a generic NP2 and a definite NP1.

### Experiment 3

The first two experiments examined whether variation in NPs at the level of structural semantics has an

influence on the object–subject difference in understanding relative clauses. In both cases, corpus data showed a strong association between type of extraction and the structural semantic characteristic of the NP that we manipulated in the experiments, but in neither case did we find that the manipulated characteristic influenced the magnitude of the sentence-complexity effect. The absence of an influence of these two distinctions suggests that it might be more fruitful to look for a lexical semantic distinction as a possible moderating factor in the object–subject difference. Previously, we found that the object–subject difference was reduced when NP2 was a pronoun or a name as compared to when it was a role description (Gordon et al., 2001). The role descriptions (e.g., doctor, barber, etc.) are fairly rich in semantic information as compared to pronouns or names that are used to introduce new characters. At a semantic level, the pronouns and names seem to convey that the referent is singular and human (as well as some stereotypical information about gender in the case of the names). The present experiment examines whether the object–subject difference is influenced by using a superordinate description conveying that same information (number and humanness). To that end, comprehension of RCs containing the expression “the person” is compared to comprehension of RCs containing the kind of role descriptions used in Experiments 1 and 2. This manipulation was used for NPI as well as for NP2 as shown in 7a and 7b.

7a The *salesman/person* that the *accountant/person* contacted spoke very quickly.

7b The *salesman/person* that contacted the *accountant/person* spoke very quickly.

The amount of semantic information conveyed by the referring expression could be expected to influence the object–subject difference through similarity-based interference if similarity is operative at the level of lexical semantics. Following this view, the object–subject difference could be reduced when a semantically lean expression is mixed with a semantically rich expression, because there is less semantic interference from the lean expression. The current experiment evaluates that possibility.

No corpus data are available on the frequency of occurrence of “the person.” Our analysis of RCs (Gordon & Hendrick, ms) did not involve coding NPs at this level. Further, sampling problems become severe when looking at the frequency of a specific expression, as compared to a class of expressions, in different sentential roles.

### Method

#### Participants

Fifty-four students from the same population as the previous studies participated in this experiment.

### Stimuli, design, and procedure

The 44 filler sentences that were used in the previous experiment were also used in this study. The experimental stimuli were modified from the previous experiments to produce six conditions also defined by two factors. Again, the first factor was type of relative clause (object vs. subject) and the second factor was type of NPs. The sentence either contained role descriptions in both the subject NP position and the embedded NP position, or the NP “the person” in one of these two positions and a role description in the other position. Thus, there were three possible NP combinations. These six experimental conditions were counterbalanced across participants as in the preceding experiments so that each sentence was presented in each of the six conditions. Each participant still received the same number of stimuli per experimental block, so each condition was presented either once or twice per block. All other aspects of the design and procedure were maintained.

### Results

Table 5 shows the mean reading times for sentences in each of the six conditions. Analyses of variance performed on the two critical reading times found a main effect of RC type where object RCs were read slower

than subject RCs both for the first critical word;  $F_1(1, 53) = 7.24$ ,  $MSE = 200,510$ ,  $p < .01$ ,  $F_2(1, 23) = 8.46$ ,  $MSE = 76,275$ ,  $p < .01$ , and for the second critical word;  $F_1(1, 53) = 17.42$ ,  $MSE = 112,647$ ,  $p < .001$ ,  $F_2(1, 23) = 11.40$ ,  $MSE = 76,493$ ,  $p < .005$ . Comprehension question accuracy was also lower for object RCs (79.5%) than for subject RCs (88.3%);  $F_1(1, 53) = 18.45$ ,  $MSE = 339.688$ ,  $p < .001$ ,  $F_2(1, 23) = 13.33$ ,  $MSE = 209.004$ ,  $p < .005$ .

No main effect of NP condition was found for the first critical reading time;  $F_1(2, 106) = .03$ ,  $MSE = 67,798$ ,  $p > .95$ ,  $F_2(2, 46) = .01$ ,  $MSE = 74,248$ ,  $p > .95$ , or the second critical reading time;  $F_1(2, 106) = 1.03$ ,  $MSE = 120,249$ ,  $p > .35$ ,  $F_2(2, 46) = .56$ ,  $MSE = 97,025$ ,  $p > .55$ . Also, no interaction of RC type and NP matching was found for either the first critical reading time;  $F_1(2, 106) = 1.48$ ,  $MSE = 77,937$ ,  $p > .2$ ,  $F_2(2, 46) = 1.14$ ,  $MSE = 44,801$ ,  $p > .3$ , or the second critical reading time;  $F_1(2, 106) = 2.02$ ,  $MSE = 75,628$ ,  $p > .35$ ,  $F_2(2, 46) = .67$ ,  $MSE = 101,951$ ,  $p > .5$ . The main effect of NP condition on comprehension question accuracy reached significance by test items;  $F_2(2, 46) = 4.56$ ,  $MSE = 88.082$ ,  $p < .02$ , but not by participants;  $F_1(2, 106) = 3.02$ ,  $MSE = 299.361$ ,  $p > .05$ . No interaction of RC type and NP condition was found for comprehension question accuracy;  $F_1(2, 106) = .20$ ,

Table 5  
Reading time results (ms) for Experiment 3

	Sentence Beginning (Before Critical Words)	Control Region RC after “that”	Critical 1 Embedded Verb or NP2	Critical 2 Main Verb	Sentence Remainder	Accuracy on Question
Object Description	418	517	702	848	525	79
	The salesman that the accountant	the accountant contacted	contacted	spoke	very quickly	
Subject Description	427	482	579	650	500	88
	The salesman that contacted the	contacted the accountant	accountant	spoke	very quickly	
Object-NP2 Person	420	531	738	812	530	76
	The salesman that the person	the person contacted	contacted	spoke	very quickly	
Subject-NP2 Person	441	484	534	612	525	86
	The salesman that contacted the	contacted the person	person	spoke	very quickly	
Object-NP1 Person		507	682	716	499	83
	The person that the accountant	the accountant contacted	contacted	spoke	very quickly	
Subject-NP1 Person	427	504	607	647	497	90
	The person that contacted the	contacted the accountant	accountant	spoke	very quickly	

The average reading time per word is shown for various sentence regions as a function of type RC extraction and type of NP1 and type of NP2. The text for each condition is presented beneath the reading time. Percent correct on answering the comprehension question for each of the conditions is also given.

$MSE = 373.974$ ,  $p > .8$ ,  $F_2(2, 46) = .25$ ,  $MSE = 132.738$ ,  $p > .75$ .

The mean reading times of the embedded NP and the embedded verb (the control region) did not show an effect of RC type;  $F_1(2, 106) = 2.68$ ,  $MSE = 24,399$ ,  $p > .1$ ,  $F_2(2, 46) = 2.26$ ,  $MSE = 12,883$ ,  $p > .1$ , of NP condition;  $F_1(2, 106) = .16$ ,  $MSE = 11,801$ ,  $p > .85$ ,  $F_2(2, 46) = .07$ ,  $MSE = 12,279$ ,  $p > .9$ , or an interaction between RC type and NP condition;  $F_1(2, 106) = 1.32$ ,  $MSE = 10,434$ ,  $p > .25$ ,  $F_2(2, 46) = .96$ ,  $MSE = 6378$ ,  $p > .35$ .

Once again, we conducted a power analysis comparable to the ones performed in Experiments 1 and 2, but with the error terms of the current experiment. Again we found that we had power above .8 to detect the presence of an interaction between RC type and sentence form had one existed.

### Discussion

Although the control region did not show an effect of RC type, the results of the analyses of the two critical words showed an object–subject difference on reading time and comprehension accuracy measures. Analysis of the mean reading time of the embedded NP and the embedded verb region is meant to control for potential word-difference effects at the first critical word, but it is reasonable to conclude that there is a main effect of RC type in this experiment, in that a main effect of RC type was observed not only at the first critical word, but also at the second critical word and in comprehension question accuracies. It could be possible to attribute effects at the second critical word to spillover from word-difference effects at the first critical word. However, it seems unlikely that spillover effects from this word difference would persist long enough to influence comprehension question accuracies. Alternatively, it is more likely that differences across RC type conditions are due to the greater difficulty of object relative clauses as compared to subject relative clauses.

No interactions were found between type of NP (description vs. “the person”) on any of the performance or comprehension measures. Despite the relative lack of semantic information and the fact that it was repeated many times in an experimental session, the expression “the person” contributed to sentence-complexity effects that were indistinguishable in magnitude from those observed with more semantically rich role descriptions.

### Experiment 4

None of the factors manipulated in the first three experiments has moderated the object–subject difference in ease of understanding sentences with RCs. Two categories of NPs defined in terms of structural semantics, indefinites and generics, were shown through corpus

studies to be dispreferred in object-extracted RCs, yet the use of indefinites and generics as NP2s did not affect the object–subject difference as compared to that observed with more favored definite NPs. Use of the expression “the person” in order to approximate the semantic characteristics of the names and pronouns previously shown to influence the object–subject difference also failed to influence the magnitude of the effect. These results are useful in understanding the characteristics of NPs that do not moderate the object–subject difference, even though they are strongly related to the prototypicality of an NP as a subject and could potentially contribute to interference in memory retrieval because of the way in which they are related to the other critical NP in the sentence.

The current study employs the expression “everyone” in order to test additional hypotheses about what critical characteristics of an NP determine whether it influences the magnitude of the object–subject difference. There are three important ways in which this expression differs from the pronoun and names that were shown by Gordon et al. (2001) to influence the magnitude of the object–subject difference. The first difference has to do with referential semantics. Names and pronouns designate individuals that do not vary in alternative, possible situations (in this sense they are “rigid designators”; Kripke, 1980); quantified pronouns like “everyone” do not share this semantic property. The second difference has to do with sentential organization. Names and pronouns cannot be modified by restrictive RCs while “everyone” can. Thus, sentence complexity in object-extracted RCs containing names or pronouns could be reduced by the redundant constraint that those expressions provide on which NP is being modified. The third difference had to do with length of the overt expression. The names and pronouns used by Gordon et al. (2001) were quite short (both in number of letters and syllables) while “everyone” is longer on both these dimensions. Thus, the lower memory-load imposed by the shorter names and pronouns could have interacted with the memory demands imposed by processing object-extracted RCs in order to produce the reductions in the object–subject difference reported by Gordon et al. (2001). Use of the expression “everyone” as NP2 in this experiment allows these hypotheses to be evaluated. A study by Warren and Gibson (2002) found that ease-of-understanding was rated as greater when a doubly center-embedded sentence included a quantified pronominal (such as everyone or no one) as its centermost NP as compared to when it contained a description.

### Method

#### Participants

Forty-eight students from the same population as the previous study participated in this experiment.

### Stimuli, design, and procedure

The 44 filler sentences that were used in the previous experiments were also used in this study. The experimental stimuli were modified from the previous experiments to produce four conditions defined by two factors. The first factor, as in the previous experiments, was type of relative clause (object vs. subject). The second factor concerned what type of NP was in the relative clause. This could either be a singular definite description or the quantified expression “everyone.” These four conditions were counterbalanced across participants as in the preceding experiments so that each sentence was presented in each of the four conditions. Each participant received the same number of stimuli per experimental block, so each condition was presented twice per block. All other aspects of the design and procedure were maintained.

### Results

Table 6 shows the mean reading times for sentences in each of the four conditions. Object RCs were once again read slower than subject RCs both for the first critical word;  $F_1(1, 47) = 5.44$ ,  $MSE = 49,967$ ,  $p < .025$ ,  $F_2(1, 23) = 5.68$ ,  $MSE = 23,895$ ,  $p < .05$ , and for the second critical word;  $F_1(1, 47) = 16.53$ ,  $MSE = 86,969$ ,  $p < .001$ ,  $F_2(1, 23) = 10.11$ ,  $MSE = 71,127$ ,  $p < .005$ . Reading times were significantly longer for sentences with descriptions than for those with quantified expressions, both for the first critical word;  $F_1(1, 47) = 9.31$ ,  $MSE = 105,425$ ,  $p < .005$ ,  $F_2(1, 23) = 16.89$ ,  $MSE = 29,066$ ,  $p < .001$ , and second critical word  $F_1(1, 47) = 15.36$ ,  $MSE = 113,732$ ,  $p < .001$ ,  $F_2(1, 23) = 37.82$ ,

$MSE = 23,089$ ,  $p < .001$ . Reading times for the control region (the mean of the reading times of the embedded NP and embedded verb) were not significantly different across RC type;  $F_1(1, 47) = .04$ ,  $MSE = 8797$ ,  $p > .8$ ,  $F_2(1, 23) = .05$ ,  $MSE = 3510$ ,  $p > .8$ , but were nearly significantly longer for descriptions than for “everyone”;  $F_1(1, 47) = 3.92$ ,  $MSE = 12,932$ ,  $p > .05$ ,  $F_2(1, 23) = 5.24$ ,  $MSE = 14,212$ ,  $p < .05$ .

Most importantly, the effect of RC type was greater for the description condition than for the quantified condition. This interaction between RC type and embedded NP type was significant for the reading time of the first critical word;  $F_1(1, 47) = 11.87$ ,  $MSE = 45,243$ ,  $p < .001$ ,  $F_2(1, 23) = 9.51$ ,  $MSE = 28,226$ ,  $p < .005$ . It was also significant for the reading time of the expanded region including the embedded NP and the embedded verb (the control region);  $F_1(1, 47) = 9.72$ ,  $MSE = 9987$ ,  $p < .005$ ,  $F_2(1, 23) = 11.29$ ,  $MSE = 4080$ ,  $p < .005$ . For the reading time of the second critical word, the interaction was significant by participants;  $F_1(1, 47) = 4.15$ ,  $MSE = 54,360$ ,  $p < .05$  but just short of being significant by items  $F_2(1, 23) = 3.92$ ,  $MSE = 28,788$ ,  $p = .060$ .

Comprehension question accuracy levels were not significant by RC type;  $F_1(1, 47) = 3.11$ ,  $MSE = 167.7$ ,  $p > .08$ ,  $F_2(1, 23) = 2.28$ ,  $MSE = 114.7$ ,  $p > .14$ , or by embedded NP type;  $F_1(1, 47) = .75$ ,  $MSE = 94.5$ ,  $p > .35$ ,  $F_2(1, 23) = .40$ ,  $MSE = 882.8$ ,  $p > .5$ . The object–subject difference in comprehension accuracy was greater for descriptions than for quantified expressions, an interaction that was significant by participants;  $F_1(1, 47) = 4.51$ ,  $MSE = 141.6$ ,  $p < .05$ , but not significant by items  $F_2(1, 23) = 2.29$ ,  $MSE = 139.4$ ,  $p > .14$ .

Table 6  
Reading time results (ms) for Experiment 4

	Sentence Beginning (Before Critical Words)	Control Region RC after “that”	Critical 1 Embedded Verb or NP2	Critical 2 Main Verb	Sentence Remainder	Accuracy on Question
Object-Definite	397	504	736	889	508	85
	The salesman that the accountant	the accountant contacted	contacted	spoke	very quickly	
Subject-Definite	411	464	555	647	487	92
	The salesman that contacted the	contacted the accountant	accountant	spoke	very quickly	
Object-Everyone	399	428	487	629	494	90
	The salesman that everyone	everyone contacted	contacted	spoke	very quickly	
Subject-Everyone	423	475	518	525	457	90
	The salesman that contacted	contacted everyone	everyone	spoke	very quickly	

The average reading time per word is shown for various sentence regions as a function of type RC extraction and type of NP2. The text for each condition is presented beneath the reading time. Percent correct on answering the comprehension question for each of the conditions is also given.

### Discussion

The current experiment, like the first three, showed a clear object–subject difference. However, unlike those experiments, this one found that the manipulated characteristics of NP2 had a significant impact on the magnitude of the effect. Differences in reading time measures of object- and subject-extracted RCs were smaller when NP2 was “everyone” as compared to when it was a role description. Differences in comprehension accuracy followed this pattern though the effect was only significant by subjects and not by items. The finding of a moderating influence of “everyone” on the object–subject difference is not consistent with the three hypotheses outlined above about the characteristics that are necessary for an NP to influence the sentence-complexity effect. In particular, it is not consistent with explanations of the findings on names and pronouns by Gordon et al. (2002) that appeal to the status of names and pronoun as rigid designators, as modifiable by restrictive RCs, or as being short expressions.

### General discussion

The four experiments reported in this paper examined how the characteristics of the NP in an embedded clause (NP2) influenced sentence-complexity effects on human understanding. Previous work had shown that the well-established difference in the ease of understanding object-extracted as compared to subject-extracted relative clauses was reduced or eliminated if NP2 was a proper name or a pronoun (Gordon et al., 2001). The current experiments showed that structural semantic (definite vs. indefinite and definite vs. generic) and lexical semantics (rich vs. lean word meaning) did not significantly influence the magnitude of the object–subject difference. However, having the quantified pronoun “everyone” as NP2 did significantly reduce the object–subject difference. The implications of these findings for theories of language comprehension are discussed below.

#### *Frequency of co-occurrence of types of NPs and RCs*

The fields of linguistics, computational linguistics and psycholinguistics have seen a resurgence of interest in statistical approaches to studying language over the last decade (e.g., Klavans & Resnik, 1996). Psycholinguistic models have been advanced in a number of areas of sentence processing where ease of processing is argued to be related to amount of experience with specific words, classes of words, or sentence structures (e.g., Juliano & Tanenhaus, 1994; Jurafsky, 1996; MacDonald, Perlmutter, & Seidenberg, 1994; Townsend & Bever, 2001), though some research has shown clear dissociations between frequency of grammatical structures and

ease of understanding (Gibson & Schutze, 1999). With respect to our current interest in relative clauses, it seems plausible a priori to expect that certain types of NPs ought to facilitate the processing of object-extracted RCs. The second NP in an object-extracted RC is the subject of the embedded clause. NPs serving as grammatical subjects have statistically predictable, though not necessary, features. The corpus analyses paired with Experiments 1 and 2 showed a strong statistical association between whether NP2 was a definite NP vs. whether it was an indefinite or generic NP. Indefinite and generic NPs were less likely to occur as NP2 in an object-extracted RC as compared to a subject-extracted RC. This pattern is consistent with the notion that indefinite and generic NPs make poor subjects, possibly because they do not refer to given information and therefore are not central to discourse (Warren & Gibson, 2002). In contrast to this finding, the experiments showed that having an indefinite or a generic as NP2 caused no change in the magnitude of the object–subject difference as compared to having a definite NP. We discuss this disjunction between the corpus data and the processing data with respect to two long-standing concerns about corpus analysis: which corpus to analyze and at what level (or grain) should the corpus be analyzed.

In arguing against corpus analysis, Chomsky (1957) pointed to the difficulty of justifying the selection of any particular corpus for analysis. In his view, language performance would inevitably be influenced by a variety of situational factors that had nothing to do with the fundamental linguistic competence that was the essence of language. An additional limitation of efforts to correlate corpus frequency with ease of processing is that it is impossible to prove that the corpus frequencies reflect the actual language experience of the participants tested in the studies. Our results do not provide general answers to these concerns, but they do show that the relation between the examined NP characteristics (definite, indefinite, and generic) and type of NP extraction (object vs. subject) is highly consistent across three corpora that differ in terms of modality of production (writing vs. speech), age of language users (adults vs. children) and proximity of interlocutors (face-to-face vs. over-the-phone). We believe that this consistency is a reasonable basis for regarding our corpus results as general with respect to the issues addressed in the present research (the relation between type of embedded NP and type of RC) and that the disjunction that we observe between frequency and processing ease cannot easily be dismissed with concerns about corpus selection.

With respect to the issue of the appropriate grain of analysis, it is important to note that our corpus analyses examined classes of NPs as they relate to types of relative clause constructions. Corpus analysis revealed the expected associations between classes of NPs and types

of RCs, but data on processing performance did not show an effect of these associations. While this disjunction could be interpreted as evidence against frequency-based explanations of sentence processing, it could also be argued that our exploration took place at the wrong level of analysis, and that either coarser-grained explanations (e.g., particular types of RCs in particular contexts) or finer-grained (e.g., particular words in different types of RCs) could correctly predict the sentence-complexity effects (see Mitchell, Cuetos, Corley, & Brysbaert, 1995 and Townsend & Bever, 2001 for discussions of how issues of the appropriate grain of analysis are problematic for the interpretation of both positive and negative results in the relation between language-use statistics and language processing).

*Noun phrases and sentence understanding*

Bever (1974) showed that the acceptability of doubly center-embedded sentences could be strongly influenced by the NPs they contain, an observation that opened a valuable window for examining how referential processing, parsing, and memory interact in the understanding of complex sentences. The current experiments add to our understanding of what characteristics of NPs influence the effect of sentence complexity on ease of comprehension. Table 7 presents a summary of the current results and those of Gordon et al. (2001), with columns indicating the classes of NPs that we have manipulated in our experiments and rows indicating important features of those classes of NPs. The table presents definite descriptions as a baseline, followed by cases where the NP manipulation did not affect ease of sentence processing, and then by cases where the NP manipulation reduced the effect of sentence complexity on processing. Our discussion of NP effects on ease of processing complex sentences will be organized around the features of the NPs (the rows of the table).

The first feature of NPs in the table is whether specific expressions were repeated in the stimulus set, which might facilitate identification of the NP. Two of the NP types that reduce processing difficulty (“you” and “everyone”) were repeated in the stimulus set seen by individual participants. However, the third type (proper names) did not involve repetition of specific expressions. Further, one of the types of NPs that had no effect on processing difficulty (“the person”) was repeated in the stimulus set. Thus, it does not appear that experience with specific stimuli during the experimental task was the basis of the influence of NPs on ease of processing complex sentences.

The next three features of NPs in the table (multiple words, mean number of letters, and mean number of syllables) capture aspects of the surface length of the NPs, a feature that could plausibly be related to the

Table 7  
Summary of results from Gordon et al. (2001) and the current experiments concerning how the characteristics of NP2 influence

	Baseline		Object–Subject difference <i>not</i> reduced by NP2 manipulation		Object–Subject difference reduced by NP2 manipulation		
	Definite Description “the salesman”	Indefinite Description “a salesman”	Generic “salesmen”	Semantically Lean Noun “the person”	Proper Name “Bob”	Indexical Pronoun “you”	Quantified Expression “Everyone”
Repeated in Stimulus Set	No	No	No	Yes	No	Yes	Yes
Multiple Words	Yes	Yes	No	Yes	No	No	No
Mean Number of Letters	10.6	8.5	8.5	9	3	3	8
Mean Number of Syllables	3.7	3.7	2.6	3	1	1	3
Rigid Designator	No	No	No	No	Yes	Yes	No
Presupposes Existence	Yes	No	No	Yes	Yes	Yes	Yes
Modifiable by an RC	Yes	Yes	Yes	Yes	No	No	Yes
Semantic Content	High	High	High	Low	Low	Low	Low
Bound by quantifier	No	Yes	Yes	No	No	No	Yes
Common Noun	Yes	Yes	Yes	Yes	No	No	No

Classes of NPs manipulated in the experiments are given as columns and the features of those classes of NPs are given in rows. In all cases, the baseline is given by having NP2 be a definite description. The next three columns are cases where there is no difference in the object–subject difference between NP2 of the type listed and the baseline condition. The final three columns show cases where the object–subject difference was significantly reduced. Examples of each class of NP2 are given below the heading.

memory demands imposed by the NPs. However, none of these features distinguishes which types of NPs affect the difficulty of processing complex sentences. All NP types that reduce difficulty of processing are one word in length, but so are generic expressions (which did not cause a reduction in processing difficulty). While two of the NP types that reduce processing difficulty (proper names and “you”) are relatively low in terms of number of letters or syllables, the third type of NP (“everyone”) is very similar in length to the expressions that have no effect on sentence complexity. This overall pattern makes it unlikely that aspects of surface length play a major role in how types of NPs influence sentence-complexity effects. If memory plays a role in such effects, then it is likely that it is memory for a more abstract level of representation than that which would be influenced by surface length.

The next three features of NPs in the table (rigid designator, presupposes existence, modifiable by an RC) relate to distinctions in how expressions refer to entities in possible worlds of meaning and more specifically in the discourse. The claim by Gibson (1998; Warren & Gibson, 2002) that complexity effects are reduced only for indexical pronouns (referring to entities that are given in the discourse environment) is a memory-based account that is built on this sort of structural semantic distinction. However, examination of the table shows that none of these features of NPs distinguishes between those NP types that reduce sentence-complexity effects on processing and those that do not.

The next NP feature (semantic content) refers to the semantic richness at the lexical level of the head of the NP. All three NP types that cause a reduction in the processing difficulty associated with sentence complexity convey relatively little semantic information at the lexical level. If the memory demands of representing an NP were related to the amount of semantic information conveyed by an NP, and if those demands interacted with the memory demands of processing complex sentences, then amount of semantic information at the lexical level could be expected to affect the processing difficulty of complex sentences. However, the expression “the person,” as a widely encompassing superordinate term, seems very comparable in terms of amount of lexical semantic information to the types of NPs that caused a reduction in the effect, yet no reduction was observed for “the person.” Thus, amount of semantic information does not seem to provide a general account of how NPs influence sentence-complexity effects.

In the semantics of discourse, indefinites and generics introduce semantic variables that are bound by quantifiers of various types (cf. Krifka et al., 1995). Proper names, pronouns, and definite descriptions, in contrast, do not. As the table illustrates, this feature of NPs cannot be responsible for the pattern of results in our experiments.

The last NP feature in the table is whether the second NP is a common noun. This is the only NP feature that accurately groups the types of NPs into those that influence sentence complexity and those that do not. Semantically, common nouns denote sets of entities or individuals that share a property such as being ‘a lawyer.’ In this respect they group with other semantic predicates such as verb phrases that denote similar sets that are defined intensionally. Determiners combine with such common nouns to make a claim about the membership of that set: thus, when composed with ‘lawyer,’ ‘the’ requires that the set intensionally defined by ‘lawyer’ be a singleton that is familiar or previously known. In an important sense, common nouns refer indirectly as compared to proper names and pronouns, which refer more directly since their semantic value can be provided extensionally rather than intensionally. The distinction between NP expressions that contain common nouns and other types of NPs provides the best available explanation of where similarity-based interference occurs in processing complex sentences (Gordon et al., 2001, 2002). There are independent syntactic and semantic analyses based on intuitive judgments of acceptability that make the same distinction in types of NPs (cf. Abney, 1987; Longobardi, 1994).

#### *Locus of interference*

While our experiments point to memory interference as a contributor to difficulty in processing complex sentences, they do not indicate where in the time course of working memory this interference takes place. Specifically, the results do not make clear whether memory interference between NPs occurs during the encoding, maintenance, or retrieval phases of working memory. If memory interference only occurred during retrieval then we might not expect to find any interactions between embedded NP types and type of RC until the matrix verb, the point when the actions that each of the NPs is performing are resolved. Instead, in Experiment 4 (as well as in the experiments of Gordon et al., 2001) we find interactions between embedded NP type and RC type both at and before the matrix verb. Thus, the current results do not allow us to ascertain definitively the locus of interference within working memory.

The experiments reported here and in Gordon et al. (2001) show that a strong object–subject difference in the processing of RCs occurs when NP2 contains a common noun, but that this difference is reduced or eliminated when NP2 does not contain a common noun. Considered alone, these facts about RC processing could support a claim that some distinctive characteristic of common nouns must be present in NP2 for the difficulty in processing object extractions



to emerge. However, in our studies on RCs, as well as in those by others, the modified NP (NP1) also contained a common noun. Thus these studies cannot rule out the possibility that interference between the memory representations for NP1 and NP2 contributed to the object–subject difference. Using cleft constructions, which allow proper names to serve as NP1, we (Gordon et al., 2001) showed that the object–subject difference was greater when NP1 and NP2 were of the same type rather than a different type. Accordingly, a unified account of the results on RCs and clefts cannot be based on the idea that common nouns are essential to the object–subject processing difference. We (Gordon et al., 2001, 2002) have argued that a unified account of this pattern can be given based on the role of interference in memory retrieval between similar representations. From the perspective of that interpretation, the current results support the idea that NPs containing a common noun form a coherent psychological class that is an important basis of similarity in memory representations.

## Appendix

The stimuli from Experiments 1 to 4 are shown below in the object-extracted form with definite descriptions. The NPs were manipulated further in the experiments as described in the text.

1. The banker that the barber praised climbed the mountain just outside of town before it snowed.
2. The dancer that the reporter phoned cooked the pork chops in their own juices on New Year's Eve.
3. The architect that the fireman liked dominated the conversation while the game was on television.
4. The waiter that the broker despised drove the sports car home from work that evening.
5. The detective that the secretary disliked clipped the coupons out with the dull scissors.
6. The judge that the doctor ignored watched the special about Colombian drug dealers on the nightly news.
7. The robber that the mailman insulted read the newspaper article about the fire.
8. The governor that the comedian admired answered the telephone in the fancy restaurant.
9. The actor that the director thanked worked in many hit movies before 1990.
10. The poet that the painter inspired wrote an autobiography after their friendship became well known.
11. The chef that the cashier distrusted called for help after the restaurant closed.
12. The aunt that the child amused made paper dolls out of the newspaper.
13. The violinist that the conductor complimented performed at Carnegie Hall for two weeks.
14. The teacher that the student questioned wrote a long science fiction novel during the summer vacation.
15. The editor that the author recommended changed jobs after a new merger was announced.
16. The tailor that the customer described worked in a small building near the bus station.
17. The admiral that the general advised reminisced nostalgically before the trip got underway.
18. The coach that the referee criticized talked publicly about the incident after the game.
19. The lawyer that the client interviewed had a very small office.
20. The plumber that the electrician called drove a grey truck.
21. The salesman that the accountant contacted spoke very quickly.
22. The clown that the magician entertained was a star.
23. The clerk that the traveler helped worked in a large foreign bank.
24. The gardener that the homeowner envied was very friendly.

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