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Pragmatic Constraint on the Interpretation of Complex Noun Phrases in Spanish and English

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Four experiments examined the role of a pragmatic constraint, the modifiability of noun phrases (NPs), in the modification of complex NPs. Experiment 1 demonstrated that NPs that had received relatively specific prior modification were less likely to take additional modification than NPs with less specific modification. This effect was obtained in both Spanish and English using 2 off-line tasks. Experiments 2 and 3 demonstrated on-line modifiability effects for both languages using a self-paced reading task. The results further suggest that although Spanish and English speakers may have opposing modification preferences, modifiability constrained their interpretations in the same direction. The results of Experiment 4 suggest that discrepancies between the off-line results from Experiment 1 and the on-line results from Experiment 3 may be due to task differences. Implications are discussed in relation to current models of sentence processing.

Although cross-linguistic investigation has played an important role in some theories of language comprehension (e.g., Bates & MacWhinney, 1979), work in sentence processing and syntactic ambiguity resolution has until recently focused primarily on English constructions. This narrow focus is unfortunate, as alternative theoretical approaches to sentence processing can make very different claims regarding the universality of processing mechanisms. Garden-path theory, for example, holds that speakers of all languages will initially resolve syntactic ambiguities through very general, universal parsing principles (Frazier, 1987). More recently, a number of theories have suggested that ambiguity resolution processes will be very sensitive to specific properties of individual languages, though these theories differ in their claims of exactly what those sensitivities might be (Cuetos & Mitchell, 1988; Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996; Gilboy, Sopena, Clifton, & Frazier, 1995; MacDonald, Pearlmutter, & Seidenberg, 1994; Mitchell & Cuetos, 1991; Trueswell & Tanenhaus, 1994). In this article, we investigate how Spanish and English speakers use pragmatic information to comprehend an ambiguity that is present in both languages. The similarities and differences in ambiguity resolution across these two languages offer some important insights into theories of sentence processing.

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Cross-Linguistic Data

The most informative cross-linguistic investigations of ambiguity resolution to date have been those that compare two or more languages that share a particular syntactic ambiguity, rather than comparisons of different ambiguities in different languages. One syntactic construction that has been particularly useful in this regard is a noun modification ambiguity with the structure *NP1 preposition NP2 modifier,* in which the final modifying phrase may modify either the more distant noun phrase, NP1, or the nearer (often termed *local*) noun phrase, NP2. A Spanish example is in (1):

(1) *La hija del coronel que tuvo el accidente*
"The daughter of the colonel who had the accident"

This ambiguity is present in a large number of languages, including English, Dutch, Spanish, French, Italian, and German (Brysbaert & Mitchell, 1996; Cuetos & Mitchell, 1988; De Vincenzi & Job, 1995; Gibson et al., 1996; Gilboy et al., 1995; Hemforth, Konieczny, & Scheepers, in press; Zagar, Pynte, & Rativeau, 1997). Comprehenders of most of these languages appear to exhibit an overall preference to interpret ambiguous modifiers as modifying the distant site (NP1), whereas English speakers tend to interpret modifiers as attaching to the local site (see Mitchell & Brysbaert, 1998, for a review). There have been a number of proposals attempting to account for these data. For example, Mitchell and Cuetos (1991) offered the *linguistic tuning hypothesis,* an exposure-based parsing mechanism for which initial parsing decisions are set in each language on the basis of the frequency distribution of the occurrence of different structures. Although tuning can theoretically occur using a variety of information (Mitchell, Cuetos, Corley, & Brysbaert, 1995), work done within this framework has typically assumed that tuning occurs at a structural grain, in which the

frequencies of syntactic structures, independent of lexical or discourse content, shape ambiguity resolution preferences.

In contrast, Gibson and colleagues (Gibson et al., 1996; Gibson, Pearlmutter, & Torrens, in press) have proposed that cross-linguistic variation in these cases is caused by differential weighting of two universal parsing principles: *recency preference,* which favors local attachment (cf. late closure, Frazier & Rayner, 1982, and right association, Kimball, 1973), and *predicate proximity,* which favors distant attachment. Gibson et al. (1996) argued that although the influence of recency is fixed across languages, the strength of predicate proximity could vary cross-linguistically. To test predictions from this model, they examined NP modification ambiguities containing three possible attachment sites and found support for both principles in both Spanish and English—local attachment was preferred, followed by distant attachment, whereas middle attachment was the least preferred.

Hemforth et al. (in press) proposed a similar two-principle model. The first of their principles attaches incoming constituents to the phrase whose head has most recently been encountered. This principle functions solely on the basis of syntactic information and is for the most part equivalent to Frazier and colleagues' (see Frazier & Rayner, 1982) late closure or Gibson and colleagues' (see Gibson et al., 1996) recency principle. The second of their principles binds anaphors to their antecedents. Thus, relative clause attachment is subject to the second principle, and preferences may vary cross-linguistically. Prepositional phrases (PPs), however, should always initially attach locally.

These accounts are notable in that the cross-linguistic differences are generally thought to rest in different treatments of structural information, not in differences in the use of nonsyntactic information cross-linguistically. Other approaches to sentence processing, however, permit a more prominent role for nonsyntactic information in sentence processing and thus in explanations of cross-linguistic variation. One of these is *construal* (Frazier & Clifton, 1996, 1997; Gilboy et al., 1995), a parsing theory with origins in the garden-path model of sentence processing (Frazier, 1987). In the garden-path model, parsing was thought to initially be influenced only by syntactic information, but in construal theory, the way in which nonsyntactic information is used depends on the type of ambiguity. In this account, ambiguities with *primary phrases,* which include phrases that could be taken as obligatory arguments of a subject or its main predicate, are handled in the two-stage process as in the garden-path model. Ambiguities with *nonprimary phrases,* including relative clauses as in the modification ambiguity in (1), are subject to construal, a mechanism that probabilistically associates a phrase into the current structure using both syntactic and nonsyntactic information. In a comparison of off-line interpretation preferences in Spanish and English noun modification structures, Gilboy et al. (1995) found support for construal with evidence that relative clause attachment to complex NPs was mediated by two types of nonsyntactic information: a noun's argument structure and referential properties of the individual NPs.

Constraint satisfaction theories allow an even larger role for nonsyntactic information in ambiguity resolution (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; MacDonald et al., 1994; Spivey-Knowlton & Sedivy, 1995; Trueswell, Tanenhaus, & Garnsey, 1994). These models propose that processing is constrained by the strength of each source of information, resulting in the partial activation of the different structural possibilities. Within this framework, difficulty in interpreting an ambiguity arises not because of inconsistency with strict parsing principles, but because the correct resolution of an ambiguity is inconsistent with probabilistic information. Although constraint-based models predict that cross-linguistic differences should occur when probabilistic information differs between languages, little cross-linguistic work has been done within this framework.

These two broad classes of theories, structural and constraint-based, differ on the role of nonsyntactic information in parsing and thus on the role of such information in explaining cross-linguistic differences. Proponents of the structural theories have emphasized the overall tendencies of a particular language, owing to structural principles (e.g., Gibson et al., 1996) or sensitivity to structural statistics (e.g., structural-level tuning; Mitchell et al., 1995). Advocates of more constraint-based accounts, however, have emphasized variation within a language, observing that interpretation preferences for individual sentences can vary a great deal as a function of the particular lexical or discourse properties of the sentence (e.g., Gilboy et al., 1995). Such variation can make cross-linguistic comparisons quite complicated, in that merely translating sentences from one language to another is not guaranteed to yield the same lexical or discourse constraints. Cross-linguistic comparisons could also be quite informative, however, in that evidence concerning the similarities and differences in use of nonsyntactic information across languages could help develop a general account of how structural and nonstructural information is integrated in sentence processing.

Thus, the contrast between the processing of modification ambiguities in Spanish and English represents a good example of both the difficulties in cross-linguistic research and the potential usefulness of such studies. There do appear to be real overall biases across Spanish and English, with a generally stronger preference for distant modification in Spanish and local modification in English (Mitchell & Brysbaert, 1998). These preferences are not absolute, however; Spanish comprehenders do not interpret NP modification ambiguities with the NP1 modification 100% of the time, and English comprehenders do not interpret these ambiguities with NP2 modification 100% of the time (Carreiras & Clifton, 1993). Ambiguities with a noticeable but not overwhelming interpretation preference are ideal candidates for examining the role of discourse and pragmatic processes in ambiguity resolution (see Britt, 1994; MacDonald et al., 1994; Spivey & Tanenhaus, 1998; Spivey-Knowlton & Sedivy, 1995).

We suggest that a pragmatic factor, which we term *modifiability,* affects interpretation of modification ambiguities in both Spanish and English. Our claim is not that this modifiability constraint is the only factor in resolution of this ambiguity; several researchers have shown how discourse

information can interact with lexical information in modification ambiguities (e.g., Britt, 1994; Spivey-Knowlton & Sedivy, 1995). Our claim is also not about the precise time course of use of this factor as opposed to other factors; this ambiguity does not always provide a precise point of disambiguation or an unambiguous baseline that would be important for time-course analyses. Instead, the issue is whether a pragmatic constraint will have similar effects in two different languages, despite the fact that the overall attachment biases in the two languages appear to go in opposite directions. The existence of at least some common pragmatic effects on ambiguity resolution cross-linguistically would have important implications for universal and language-specific factors in sentence processing. Following a description of modifiability, we discuss the predictions of alternative accounts of cross-linguistic ambiguity resolution.

NP Modifiability

Although much of the debate over the influence of nonsyntactic information has focused on the role of lexical information in sentence processing, a number of studies have demonstrated the important influence of pragmatic information on processing (Altmann & Steedman, 1988; Altmann, van Nice, Garnham, & Henstra, 1998; Crain & Steedman, 1985; Spivey-Knowlton & Sedivy, 1995). Speakers often choose to modify the nouns in an utterance, as in *the big cat* or *the cat on the rug.* Modification serves many functions in the discourse, including singling out a particular entity from a set of possible referents; *the big cat* distinguishes one cat from a smaller one, and *the cat on the rug* distinguishes this cat from the one on the chair (see Birner & Ward, 1994; Kadmon, 1990, for discussion of uniqueness). In most discourses, the amount of modification needed to distinguish one entity from the set of potential referents is fairly small. Given only a few cats in a room, for example, it is not necessary to say *the big Persian cat with two white paws and one black ear that's sitting on the stack of newspapers* to distinguish it from other cats, and the addition of this nonessential information flouts Grice's Maxim of Quantity: Speakers should be concise and say no more than is necessary (Grice, 1975).

Although previous work on referential theory (e.g., Altmann & Steedman, 1988; Crain & Steedman, 1985) and on the semantics of reference in general (e.g., Enç, 1991; Kadmon, 1990) has divided NPs into discrete categories (e.g., specific vs. nonspecific or unique vs. nonunique), in the present article we propose that modifiability is a continuous variable. Our claim is that comprehenders are sensitive to the fact that a modest amount of modification is the norm, such that the more modification an NP has received at a certain point in the discourse, the less additional modification is expected. When applied to parsing of ambiguous modifying expressions, the claim is that an NP that has received little prior modification is a better candidate for additional modification than an NP that has already been extensively modified.

If the degree of prior modification affects comprehenders' perceptions of the felicity of further modification, then these computations could have substantial effects on ambiguity resolution. That is, in NP1 preposition–NP2 modifier structures, manipulations of the degree of modification that NP2 receives (e.g., with prenominal modification, as in *the famous Shakespearean actress*) should decrease the acceptability of this site for further modification, and thus interpretations of an ambiguous phrase modifying the alternative NP1 site should increase as prior modification to the NP2 site increases. This is the hypothesis that is explored in the four experiments below.

Because the Gricean principles underlying the modifiability predictions are thought to be universal pragmatic principles (Green, 1990), we also predict that modifiability should affect ambiguity resolution in complex NP modification structures in a similar manner for both Spanish and English. Thus, even though the two languages may exhibit opposing attachment preferences, we expect that modifiability should constrain preferences in NP1 preposition–NP2 modifier structures, such that distant attachment will become more likely as NP2's modifiability decreases. Experiment 1 is an off-line study that uses both ratings and sentence completion tasks to assess directly (a) whether prenominal modification affects the felicity of further modification in Spanish and English and (b) whether variations in prenominal modification affect sentence completions. Experiments 2–3 then investigate how manipulations of prenominal modification affect the interpretation of ambiguous modifying phrases during on-line processing. Experiment 4 examines differences observed between the off-line English results of Experiment 1 and the on-line English results of Experiment 3.

Experiment 1

The purpose of this experiment was to determine off-line attachment preferences to complex NPs in Spanish and English and whether these preferences are affected by an NP's modifiability. Spanish- and English-speaking participants were given either a ratings task (Experiment 1a) or a sentence completion task (Experiment 1b) in their native language. For the ratings task, pairs of NPs were created, containing the same noun and number of words, that differed in the relative specificity of their prenominal modification. For any given item, the *easy modification* condition was less specific than the *difficult modification* condition. Participants were given one member of each of the pairs and were asked how difficult it would be to modify them using a phrase beginning with *con,* for Spanish participants, or *with,* for English participants, testing the hypothesis that participants would rate the less specific member of a pair as easier to further modify than the more specific one. For the sentence completion task, the NPs rated in Experiment 1a were placed in the NP2 position in the structure NP1 preposition NP2 *con/with,* and participants were instructed to complete the fragments with the first continuation that came to mind. Responses were scored as attaching to one of the two NPs. We predicted that fragments containing NP2s that were rated as difficult to modify would be less likely to

receive local (i.e., NP2) modification than those whose NP2 was an NP rated as easy to modify.

Researchers working on cross-linguistic issues frequently use direct translations so as to be able to make direct comparisons between languages (e.g., Gibson et al., 1996). In developing our Spanish and English materials, we made a decision that stands in contrast with this tradition in that direct translations between Spanish and English materials were purposefully avoided. Our view is that the use of direct translations is not always the best strategy in studying cross-linguistic sentence processing, as cognate sentences may often sound awkward in one language. For example, consider the Spanish phrase *las sábanas de una cama.* This item sounds natural in Spanish, but the English translation, *the sheets of a bed,* is extremely awkward; English speakers would typically say *the bed sheets* to convey the intended meaning. Thus, direct translations are not guaranteed to yield the same lexical and discourse constraints; if we had used direct translation in this case, we would be comparing Spanish comprehenders' performance on a natural item with English comprehenders' performance on an awkwardly phrased item. To avoid this confound, we created items that sounded relatively natural in each language, without the constraint that Spanish and English items be close translations of one another.

Method: Experiment 1a

Participants

Spanish. Thirty-two University of Southern California undergraduates participated as volunteers. All participants were native speakers of Latin American dialects of Spanish and were from one of the following countries: Argentina, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Mexico, Nicaragua, or Venezuela. They were recruited from international students' associations and similar venues, so as to obtain participants for whom Spanish was the first language acquired and was still used often.

English. Sixty University of Southern California undergraduates participated for partial credit in an introductory psychology class. All were native speakers of American English.

Materials

Spanish. Thirty-two pairs of simple two- or three-word Spanish NPs were created. Both members of a pair contained the same noun and number of words, but the type of prenominal modification was manipulated at two levels. For the easy modification condition (henceforth the *easy* condition), stimuli were designed so that the NP was left as vague and unspecific as possible. This condition contained NPs that were unmodified and contained an indefinite article (e.g., *una mansión,* "a house"; *un país,* "a country"). For the difficult modification condition (henceforth the *difficult* condition), the NPs either contained a definite article or a possessive pronoun, and several items contained additional modification (e.g., *mi mansión,* "my house"; *el país vecino,* "the neighboring country"). Two lists were created in a counterbalanced fashion, with equal numbers of easy and difficult items. Each item appeared only once on each list.

English. Forty-two pairs of simple two- to four-word English NPs were created. Both members of a pair contained the same noun and number of words, again manipulating the type of prenominal modification. The easy condition contained unmodified NPs or NPs with prenominal modification that set up a contrast set (e.g., *only,* see Ni & Crain, 1990; or superlatives, e.g., *the only hall, the largest lab*). For some items, prenominal modification that did not identify the NP as a specific instance was used to control for length across conditions (e.g., *an enamel sink*). In contrast, the difficult condition contained either possessive modification (e.g., possessive nouns or pronouns) or prenominal adjectives that identified NP2 as a specific item (e.g., *my front hall, his lab, our kitchen sink*). Two counterbalanced lists were created.

Procedure

The procedure was identical for both the Spanish and English versions. Participants received the list of NPs on paper and were instructed, in their native language, to rate on a 7-point scale how easy it would be to continue each NP with a phrase beginning with *con* (Spanish version) or *with* (English version). A rating of 1 indicated that the NP would be very difficult to further modify with a *con/with* phrase, and a rating of 7 indicated that the NP would be very easy to further modify. The entire procedure took about 15 min.

Results: Experiment 1a

Spanish

For the Spanish items, the overall mean rating was 4.85 ($SD = 1.02$). The easy condition (5.23, $SD = 1.00$) was rated as being significantly easier to further modify than the difficult condition (4.47, $SD = 0.89$), $F_1(1, 31) = 18.72, p < .001$; $F_2(1, 31) = 25.69, p < .001$. ($F_1$ indicates participant analysis and F_2 indicates item analysis throughout.)

English

For the English items, the mean overall rating was 4.47 ($SD = 0.84$). As in Spanish, the easy condition (4.79, $SD = 0.82$) was rated significantly easier to further modify than the difficult condition (4.15, $SD = 0.74$), $F_1(1, 59) = 48.68, p < .001$; $F_2(1, 41) = 17.83, p < .001$.

These results confirm our claim that the type of prenominal modification an NP has received affects the perceived felicity of further modification. Experiment 1b used the same NPs as in Experiment 1a and investigated the effects of modifiability on NPs embedded in sentence contexts, using a sentence completion task. The prediction was that sentence completions would be more likely to modify the easy NPs than the difficult ones.

Method: Experiment 1b

Participants

Spanish. Twenty-eight University of Southern California undergraduates participated as volunteers. All were native speakers of Latin American dialects of Spanish and were from one of the following countries: Argentina, Bolivia, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Mexico, Nicaragua, Uruguay, or Venezuela. They were recruited in a manner similar to that used in Experiment 1a. None had participated in Experiment 1a.

English. Sixty-four University of Southern California undergraduates participated for partial course credit in an introductory

psychology course. All were native speakers of American English. None had participated in Experiment 1a.

Materials

Spanish. Thirty-two pairs of Spanish sentence fragments with the NP1–preposition–NP2–*con* structure were created using the Spanish NPs from Experiment 1a in the NP2 position; the easy condition used the easy NPs from Experiment 1a, whereas the difficult condition used the difficult NPs from Experiment 1a. All NP1s consisted of a definite determiner followed by a noun. Examples are presented in (2):

(2) a. NP2 rated as easy to modify:
Las sábanas de una cama con
"The sheets of a bed with"
b. NP2 rated as difficult to modify:
Las sábanas de mi cama con
"The sheets of my bed with"

English. Forty-two pairs of English sentence fragments of the NP1–preposition–NP2–*with* structure were created using the English NPs from Experiment 1a in the NP2 position; the NP2 easy condition used the easily modified NPs in NP2 position, whereas the NP2 difficult condition used the NPs that were difficult to modify. Examples are presented in (3):

(3) a. NP2 rated as easy to modify:
The computer down the only hall with
b. NP2 rated as difficult to modify:
The computer down my front hall with

Procedure

The procedure was identical for both the Spanish and English versions. Stimuli were presented on paper in random order. Two presentation lists were created with an equal number of items from each condition. Each item appeared only once on each list. Two practice items of the same structure were composed. Participants were instructed in their native language to complete the experimental items with the first thought that came to mind. The entire procedure took about 15 min.

Results: Experiment 1b

Completions were scored by two native Spanish speakers (for Spanish completions) or English speakers (for English completions) as attaching either to NP1 or to NP2, and any ambiguous attachments were excluded from the analysis (none of the Spanish completions and 1% of the English completions).

Spanish

Overall, 69% (SD = 26.2) of all attachments were to NP1. A single-sample t test revealed that overall performance differed significantly from chance, $t(27) = 2.23, p < .05$, indicating a robust NP1 attachment preference. As shown in Figure 1, this preference was mediated by modifiability, such that there were significantly more NP1 attachment completions in the NP2 difficult condition than in the NP2 easy condition, $F_1(1, 27) = 15.87$, $p < .001$; $F_2(1, 31) = 12.75, p < .001$.

English

Overall, 80% (SD = 15.7) of attachments were to NP1. A single-sample t test revealed that overall performance differed significantly from chance, $t(63) = 5.98$, $p < .01$, indicating an NP1 attachment preference. Again, as shown in Figure 1, this preference was mediated by modifiability, such that there were significantly more NP1 attachment completions in the NP2 difficult condition than in the NP2 easy condition, $F_1(1, 63) = 59.72$, $p < .001$; $F_2(1, 41) = 12.07, p < .001$.

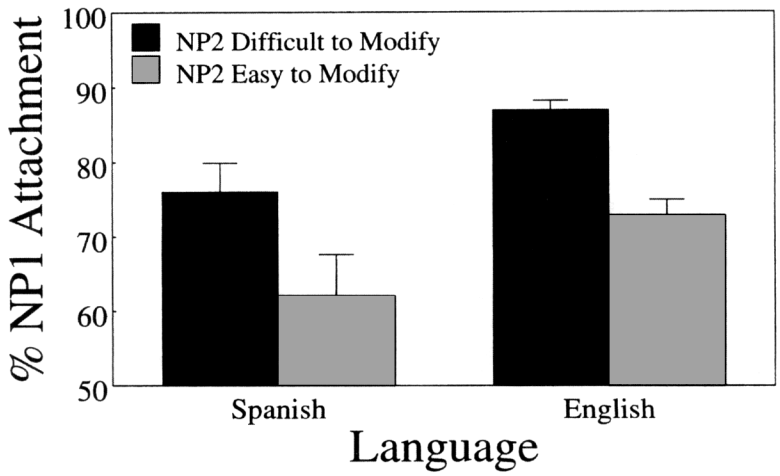

Figure 1. Mean percentage of NP1 completions for both Spanish and English participants, with standard error bars computed across participants. NP1 = distant noun phrase; NP2 = local noun phrase.

Discussion

Together, the results from Experiments 1a and 1b suggest a link between modifiability and ambiguity resolution in both Spanish and English. Experiment 1a demonstrated that, for a given item, the relatively specific version was rated significantly harder to further modify than the less specific version. Experiment 1b demonstrated that when the NPs rated as difficult were placed in the NP2 position of NP1–preposition–NP2–*con/with* fragments, participants were more likely to modify NP1 than when the NPs rated as easy were used. The results further demonstrated that this pragmatic constraint holds cross-linguistically. Figure 1 shows that the pattern of results for both Spanish and English was quite similar. Although the results in both languages evidenced a general preference for distant attachment, this preference was stronger for the difficult condition; as the rated modifiability of an NP decreased, the likelihood that it would take modification compared with an easy NP decreased.

The overall distant (NP1) attachment preference for PPs in Spanish is generally consistent with other Spanish studies of relative clause attachment (Carreiras & Clifton, 1993, in press; Cuetos & Mitchell, 1988; cf. Gibson et al., 1996; Gilboy et al., 1995). The NP1 attachment preference found here for English, however, differs from the general local (i.e., NP2) attachment preference for relative clauses (Gibson et al., 1996). The overall distant attachment preference for both languages is also inconsistent with on-line data that suggest a general local attachment preference for PPs in Italian (De Vincenzi & Job, 1995) and German (Hemforth et al., in press).

Some of this variability is likely due to our modifiability manipulation, which was not considered in these prior studies. In fact, even in our NP2 easy condition, nonspecific prenominal modification was used to control for length. Thus, even our easy modification condition may have been more specific than previous studies, which typically had no prenominal modification at all. Another potential factor may be the particular choice of stimulus phrases. The set of items in any two experiments may have different attachment biases, and in placing a premium on phrase naturalness in both languages, our stimulus items may be quite different in character from those in studies that emphasized direct translation across languages. It is also possible that some of this variation in attachment preference owes to the form of measurement; some researchers have suggested that on-line tasks may draw on more implicit processing, compared with off-line tasks, which often require more explicit forms of judgment (Tyler, 1992). Before exploring how attachment preferences might vary with the task, we must first establish the extent to which on-line preferences for our stimuli vary from the off-line ones observed in Experiment 1. Experiments 2–3 addressed this question and also assessed whether the hypothesized effects of modifiability were obtained in an on-line task.

Experiment 2

This experiment assessed on-line attachment preferences in Spanish, and Experiment 3 assessed the same for English. We began with Spanish because it appears to be the more straightforward case, in that our off-line data appear to be more consistent with other studies for Spanish than for English.

To collect on-line reading data reflecting the relative difficulty of NP1 versus NP2 attachment, we created complete sentences from fragments used in Experiment 1b with information that semantically disambiguated the attachment of the ambiguous *con* phrase. A self-paced reading task was used to collect reading times for each word in these sentences, with the critical region being the disambiguating *con* phrase and the next several words.

Reading times in the critical regions will be relevant to two issues. The first of these is whether on-line measures will replicate the NP1 attachment bias observed for these items in Experiment 1. This pattern would be revealed by a main effect of attachment in the disambiguation region, such that PPs with an NP1 attachment disambiguation yield shorter reading times than those with an NP2 attachment disambiguation. Second, we investigated the role of modifiability in ambiguity resolution. An effect of modifiability would be revealed by an interaction of attachment and modifiability in the disambiguating regions, such that reading times are shorter for NP1 attachment in the difficult NP2 modification condition versus the easy NP2 modification condition.

Method

Participants

A total of 40 students participated; 26 of these were university students from Los Angeles and the remaining 14 were university students from Caracas, Venezuela. The Los Angeles participants were recruited in the same manner as in Experiment 1 and did not participate in Experiment 1. All participants were speakers of Latin American dialects of Spanish and were from one of the following countries: Argentina, Chile, Colombia, Cuba, El Salvador, Ecuador, Mexico, Nicaragua, or Venezuela. All of the Venezuelan participants were native speakers of Venezuelan Spanish. All participants either were volunteers or were paid for participation. An additional 5 participants were excluded from subsequent analyses for missing more than 20% of the comprehension questions.

Materials

Complete sentences were created from the 28 Spanish fragments used in Experiment 1b that evidenced the most robust differences in attachment preference between conditions. Endings that semantically disambiguated the attachment of the ambiguous PP modifier as attaching to either NP1 or NP2 were created, yielding four conditions per item (NP2 difficult vs. NP2 easy × NP1 vs. NP2 modification disambiguation). The disambiguations all consisted of a three-word PP of the form *con*–adjective–noun or *con*–noun–adjective, as some adjectives in Spanish are prenominal and others are postnominal. Thus, the onset of the disambiguation information is variable across items but should be available by the third (and last) word of the PP. A passive verb phrase followed the PP. The passive phrase was completed by either a simple NP (e.g., ... *fueron otorgadas territorios propios,* "... were given their own

Table 1
Sample Materials From Experiment 2

Condition	Sample sentence
NP2 easy-to-modify condition	
NP1 attachment disambiguation	*La computadora de una oficina con pantalla gigante fue comprada para agilizar el trabajo.* "The computer of an office with a giant screen was bought to speed up work."
NP2 attachment disambiguation	*La computadora de una oficina con pocos empleados fue comprada para agilizar el trabajo.* "The computer of an office with few employees was bought to speed up work."
NP2 difficult-to-modify condition	
NP1 attachment disambiguation	*La computadora de mi oficina con pantalla gigante fue comprada para agilizar el trabajo.* "The computer of my office with a giant screen was bought to speed up work."
NP2 attachment disambiguation	*La computadora de mi oficina con pocos empleados fue comprada para agilizar el trabajo.* "The computer of my office with few employees was bought to speed up work."

Note. NP1 = distant noun phrase; NP2 = local noun phrase.

land"), a PP (e.g., . . . *fue encontrado en el basurero,* ". . . was found in the trash"), or adjunct predication (e.g., . . . *fueron matadas una por una,* ". . . were killed one by one"). These items were combined with 5 practice and 30 filler items to create four counterbalanced presentation lists. A yes/no comprehension question was composed for each item. An example of the experimental items is given in Table 1, and all materials appear in Appendix A.

Procedure

The materials were presented on a computer screen using a single-word, self-paced reading task. All materials and written instructions were presented in Spanish, and the experimenter, a native speaker of Spanish, spoke only in Spanish during the testing session. At the beginning of each trial, a line of dashes appeared on the screen, with each dash representing a character in the sentence. Participants then pressed a key to see each word of the sentence in a noncumulative fashion (Just, Carpenter, & Woolley, 1982). The keypress that ended the presentation of the last word of a sentence triggered the presentation of the yes/no comprehension question. Participants answered the question by pressing a key marked either "sí" or "no" and were given feedback on screen about their accuracy. Testing occurred either at the University of Southern California or in a quiet testing room in Caracas, Venezuela. Following the practice items, the experimental items and fillers were presented in random order. The experimental session took less than 25 min.

Results and Discussion

For each participant, we calculated a regression equation across all experimental items and fillers to determine a residual reading time for each word (Ferreira & Clifton, 1986). The motivation for this conversion was twofold: (a) to make comparison across conditions that varied in number of characters possible and (b) to reduce variance across participants due to different overall reading times and sensitivity to variations in word length. The length-adjusted reading times that were more than two standard deviations from the mean were trimmed for each word in each condition, which excluded about 4% of all observations. Overall, participants answered 97% (SD = 3.96) of the comprehension questions correctly, and only items that were answered correctly were included in analysis.

Reading times in the critical regions and next several words are shown in Figure 2, and F values from analyses of variance (ANOVAs) are contained in Table 2. There were no reliable effects for the first two words in the temporarily ambiguous PP, but there was a reliable Modifiability × Attachment Disambiguation interaction at the disambiguating word at the end of the PP, Position 3. This interaction was such that for the NP2 easy condition, reading times did not differ as a function of attachment disambiguation, but for the NP2 difficult condition, reading times for the NP2 attachment disambiguation were significantly longer than

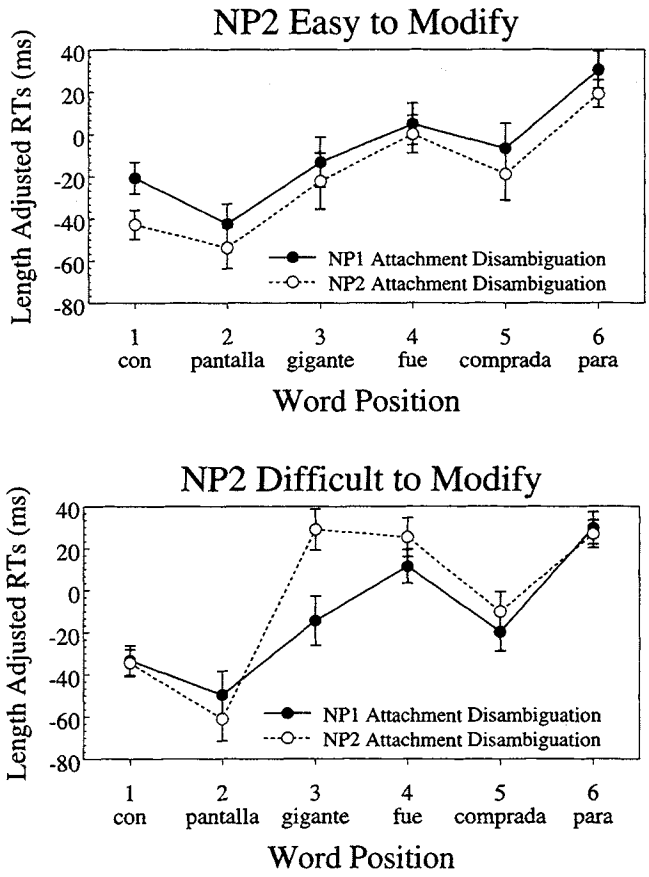

Figure 2. Mean length-adjusted reading times (RTs), with standard error bars computed across participants, for both the NP1 and NP2 attachment disambiguation conditions from Experiment 2. NP1 = distant noun phrase; NP2 = local noun phrase.

for the NP1 attachment disambiguation. There were no reliable effects at any subsequent word positions.

To determine if attachment preference did indeed shift as a result of the modifiability manipulation, we performed pairwise comparisons between NP1 and NP2 attachment at each level of modifiability at Word Position 3. In the NP2 easy condition, there was no significant effect of attachment ($Fs < 1$). In the NP2 difficult condition, however, there was a significant effect of attachment, such that reading times for NP1 attachment were significantly shorter than for NP2 attachment, $F_1(1, 39) = 11.44$, $p < .01$; $F_2(1, 27) = 6.06$, $p < .05$.

Unadjusted means from the data used in the analyses are presented in Appendix B. The results from ANOVAs on the unadjusted means are also presented in Appendix B, and they reveal the same pattern of results as in the length-adjusted data, including the crucial significant interaction of modifiability and attachment at Word Position 3, $F_1(1, 39) = 6.30$, $p < .05$; $F_2(1, 27) = 4.77$, $p < .05$.

To determine if any reading time patterns varied with participant population, we carried out analyses on unadjusted reading times with testing location (Los Angeles vs. Caracas) as a variable. There was no main effect of population on reading times, $Fs < 1$ (overall mean reading times: Los Angeles = 460 ms, $SD = 121$ ms; Caracas = 490 ms, $SD = 98$ ms). To ensure that the critical pattern of results at Word Position 3 did not differ with population, we carried out an additional ANOVA with attachment, modifiability, and population as independent variables. There was no main effect of population, and there were no significant interactions between population and modifiability or population and attachment (all $Fs < 1.5$).

This pattern of reading times clearly replicates the off-line Spanish results from Experiment 1. Both experiments demonstrated a robust effect of modifiability in Spanish, such that as the modification to an NP became more specific, participants were less likely to interpret it as receiving subsequent modification. The results of Experiment 2 are also consistent with other studies showing that Spanish does not exhibit a local attachment bias (e.g., Cuetos & Mitchell, 1988), although many of these studies have found a distant attachment bias, which was present only in our NP2 difficult condition. In Experiment 3, we used the same on-line methodology as in Experiment 2 to investigate the effects of NP modifiability in English, which has been claimed to have a general local attachment preference (Frazier, 1987; Frazier & Rayner, 1982; Gibson et al., 1996).

Experiment 3

Method

Participants

Forty-eight University of Southern California undergraduates were paid for participation. All were native speakers of American English, and none had participated in Experiment 1. Six additional participants were excluded from the analyses either for having a mean reading time more than two standard deviations from the overall mean or for missing more than 20% of the comprehension questions.

Materials

As in Experiment 2, complete sentences were created from the 32 English fragments used in Experiment 1b that demonstrated the most robust differences in attachment preference between conditions. Endings that semantically disambiguated the attachment of the ambiguous PP modifier as attaching to either NP1 or NP2 were created, yielding four conditions per item. The disambiguations all consisted of a three-word PP of the form *with*–adjective–noun, so that disambiguating information became available by the third word of the PP. A passive verb phrase followed (e.g., . . . *was used by* . . .), the agent of which was a simple, definite NP (e.g., . . . *the programmer*). See Table 3 for an example. All materials appear in Appendix C. The stimuli were combined with 76 filler items and 6 practice items to create four lists with each stimulus appearing once in each list. A yes/no comprehension question was composed for each item.

Procedure

As in Experiment 2, the materials were presented on a computer screen using a single-word, self-paced reading task. The experimental session took less than 25 min.

Results and Discussion

As in Experiment 2, length-adjusted reading times were calculated for each word, and only items for which the comprehension question was answered correctly were in-

Table 2
Results From Analyses of Variance on Both Variables and Their Interaction at Each Critical Sentence Position From Experiment 2

		Disambiguation		Modifiability		Interaction	
Position	Example	F_1	F_2	F_1	F_2	F_1	F_2
1	*con*	3.18	2.46	0.13	0.06	3.18	2.37
2	*pantalla*	1.51	1.64	0.76	0.18	0.00	0.03
3	*gigante*	2.29	1.80	3.70	2.33	5.82*	4.34*
4	*fue*	0.31	0.38	3.61	3.94	1.48	2.21
5	*comprada*	0.01	0.00	0.05	0.04	1.23	2.43
6	*para*	1.37	1.14	0.36	0.31	0.34	0.46

Note. Degrees of freedom for all F_1s = (1, 39) and for F_2s = (1, 27).
*$p < .05$.

Table 3
Sample Materials From Experiment 3

Condition	Sample sentence
NP2 easy-to-modify condition	
NP1 attachment disambiguation	The computer down the only hall with expanded memory was used by the programmer.
NP2 attachment disambiguation	The computer down the only hall with drinking fountains was used by the programmer.
NP2 difficult-to-modify condition	
NP1 attachment disambiguation	The computer down my front hall with expanded memory was used by the programmer.
NP2 attachment disambiguation	The computer down my front hall with drinking fountains was used by the programmer.

Note. NP1 = distant noun phrase; NP2 = local noun phrase.

cluded in analysis. Overall, participants answered 94% (SD = 5.14) of the comprehension questions accurately. The length-adjusted reading times that were more than two standard deviations from the mean were trimmed for each word in each condition, which excluded less than 4% of all observations.

Mean length-adjusted reading times, trimmed at two standard deviations by subject and conditions, are shown in Figure 3. Results of ANOVAs on length-adjusted reading times are in Table 4. As in Experiment 2, the critical regions for this study included the temporarily ambiguous three-word PP, which was disambiguated by its last word (the noun), and the next several words, over which effects of processing difficulty might be observed. There were no significant effects of any factor at the introduction of the ambiguity, the word *with*. There was a main effect of modifiability at Word Position 2, the prenominal adjective, which was significant by participants and marginally significant by items, such that reading times were longer for the NP2 difficult condition than for the NP2 easy one. There was no significant main effect of attachment disambiguation, and the interaction of these variables was not significant. Reading times at Word Position 3, which was the definite disambiguation ("memory" in Figure 3), showed a clear effect of modifiability on attachment with a reliable Modifiability × Attachment interaction at this position. This interaction also carried over to the next word position, "was" in Figure 3. The nature of this interaction was that for the NP2 easy condition (Figure 3, top), reading times were significantly longer for the NP1 attachment disambiguation than for the NP2 attachment disambiguation. However, for the NP2 difficult condition (Figure 3, bottom), there was no significant difference between the NP1 and NP2 attachment disambiguations. There were also reliable main effects of modifiability at Word Positions 4 and 5, the verb phrase, such that reading times were significantly longer for the NP2 difficult condition than for the NP2 easy condition. This result suggests that when rather specific prenominal modification discourages the generally favored local modification, reading times increase over the less specific NP2 easy condition. There were no reliable effects at any of the subsequent words.

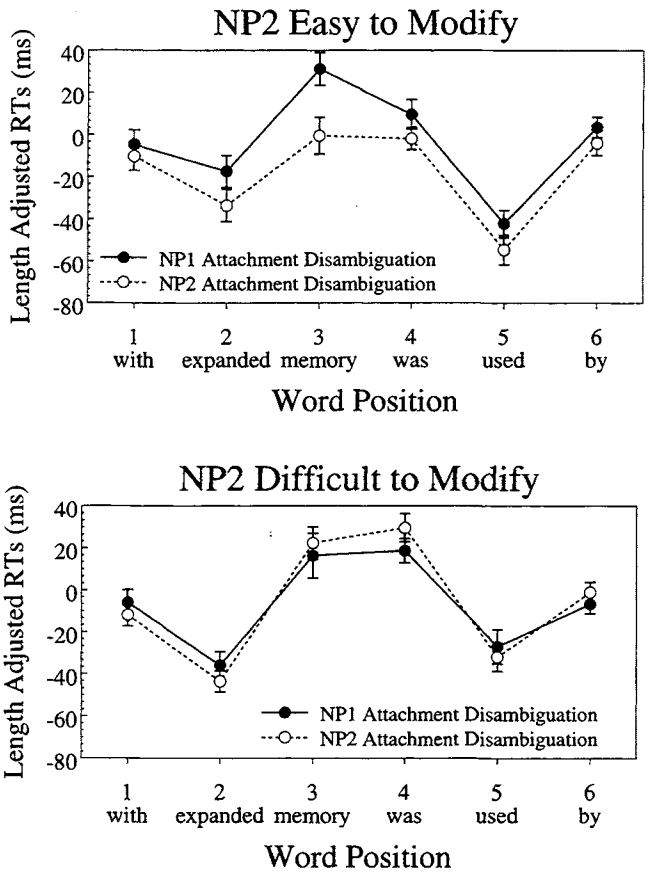

Figure 3. Mean length-adjusted reading times (RTs), with standard error bars computed across participants, for both the NP1 and NP2 attachment disambiguation conditions from Experiment 3. NP1 = distant noun phrase; NP2 = local noun phrase.

As in Experiment 2, pairwise comparisons were performed to determine if attachment preference shifted as a result of the modifiability manipulation at Word Position 3. In the NP2 easy condition, there was a significant effect of attachment, $F_1(1, 47) = 7.52, p < .01$; $F_2(1, 31) = 7.60, p < .01$, such that reading times for NP2 attachment were significantly shorter than for NP1 attachment. In the NP2 difficult condition, there was no significant effect of attachment (Fs < 1).[1]

[1] A reviewer noted that four of our items used *only* in the prenominal modification for the easy condition and had some concern that these items might act differently than the others. To address this concern, we conducted ANOVAs excluding these items and found the same pattern of results, including the Modifiability × Disambiguation interaction at Word Position 3, $F_1(1, 47) = 9.54, p < .01$; $F_2(1, 27) = 7.54, p < .05$, and effects in the pairwise comparison, such that the easy condition evidenced a

Table 4
Results From Analyses of Variance on Both Variables and Their Interaction at Each Critical Sentence Position From Experiment 3

Position	Example	Disambiguation		Modifiability		Interaction	
		F_1	F_2	F_1	F_2	F_1	F_2
1	*with*	1.06	1.17	0.02	0.00	0.13	0.10
2	*expanded*	2.10	3.10	6.05*	4.05	0.23	0.37
3	*memory*	1.73	1.98	1.72	0.84	6.52*	5.87*
4	*was*	0.09	0.14	9.04*	10.83*	4.26*	5.90*
5	*used*	3.09	3.01	13.01*	18.36*	0.09	0.18
6	*by*	0.03	0.12	0.84	1.82	1.66	1.14

Note. Degrees of freedom for all F_1s = (1, 47) and for F_2s = (1, 31).
*$p < .05$.

Unadjusted means from the data used in the analyses are presented in Appendix D. The results from ANOVAs on the unadjusted means are also presented in Appendix D, and they reveal the same pattern of results as in the length-adjusted data, including the crucial significant interaction of modifiability and attachment at Word Position 3, $F_1(1, 47) = 6.15, p < .05$; $F_2(1, 31) = 6.12, p < .05$, and Word Position 4, $F_1(1, 47) = 4.44, p < .05$; $F_2(1, 31) = 4.33, p < .05$.

Consistent with the results from Experiment 1, the results of Experiment 3 demonstrated the influence of the modifiability of an NP on ambiguity resolution in English. In both experiments, PP modification of NP2 is less felicitous in the NP2 difficult modification condition than the NP2 easy modification condition. The pairwise comparison at Word Position 3 also offers some support for claims that English speakers prefer local modification (e.g., Carreiras & Clifton, in press; Frazier, 1987; Gibson et al., 1996; Phillips & Gibson, 1997), although the NP2 attachment preference occurred only in the NP2 easy condition. The relatively specific prenominal modification in the NP2 difficult condition seemingly erased the local attachment preference. Thus, the results of Experiments 2 and 3 showed a general trend for English-speaking participants to prefer local attachment more than Spanish-speaking participants, but there was also a fair amount of variability in overall attachment patterns between experiments. These differences were overlapping, such that in the English NP2 difficult and the Spanish NP2 easy conditions, no strong preference for either local or distant attachment was observed. These overlapping attachment patterns are inconsistent with models, such as structural-level tuning, that claim that an individual language will prefer only the most frequent attachment pattern. Our data further suggest an important role for pragmatic and discourse information in any explanation of attachment preferences.

Although participants showed similar sensitivity to the modifiability manipulation across all three experiments, there were discrepancies between the English off-line results from Experiment 1b and the results of Experiment 3. In Experiment 1b, sentence completions revealed a distant attachment preference, whereas reading times in the present experiment were longer for NP1 than NP2 attachment in the NP2 easy condition, suggesting a local attachment preference.

Discrepancies between off- and on-line data have been given a number of alternative interpretations in the literature. Within work on modification ambiguities, De Vincenzi and Job (1995) interpreted differences in off- and on-line data as supporting a two-stage parsing theory (e.g., garden-path theory). An alternative interpretation takes into account differing task demands. There were two important differences between the off-line sentence completion task in Experiment 1b and the on-line self-paced reading task in Experiment 3 that might explain the differing results. First, the off-line task imposed less time constraint than did the on-line one; second, the off-line task had a stronger production component (participants produced completions to sentence fragments), whereas the on-line task simply required participants to comprehend the sentences. The sentence completion task might have encouraged more NP1 attachment, because participants needed to produce completions relevant to the overall topic of the fragment, and in all cases, NP1 would have been the subject of the completed sentence, possibly making it more prominent than NP2. This hypothesis predicts that a more comprehension-based off-line task would yield less of an NP1 attachment preference than was observed in the completion task in Experiment 1b. We explored this possibility in Experiment 4.

Experiment 4

This experiment assessed the effect of modifiability and overall attachment preferences in English using an off-line task in which participants simply rated the sentences from Experiment 3 for naturalness. This task shares aspects of both self-paced reading and sentence completion: As in

preference for local attachment, $F_1(1, 47) = 10.23, p < .01$; $F_2(1, 27) = 9.46, p < .01$, that was not observed in the difficult condition (Fs < 1.5, ps > .2). Additionally, because the modifiability manipulation differed somewhat between items, ANOVAs were performed with type of modification (adjectival vs. possessive noun/pronoun) as a factor. The results demonstrate that this factor did not have a significant effect or interact with the variables, either overall (all Fs < 1.5, all ps > .15) or at Word Position 3 (all Fs < 2.1, ps > .15). Thus, although these factors may exhibit differential effects on processing, these differences are not responsible for the effects reported here.

self-paced reading, naturalness rating is largely a comprehension task, and as in sentence completion, the task is off-line and requires a specific choice from the participants. If the discrepancy between the English results from Experiment 1b and Experiment 3 was due to temporally distinct processing stages (De Vincenzi & Job, 1995), then the results of Experiment 4 should mirror those of sentence completion in Experiment 1b, namely, overall higher naturalness ratings for NP1 completions than for NP2 completions, reflecting a distant attachment bias. If task demands constrain the overall distant–local attachment preference, however, then the rating results in Experiment 4 should not correspond exactly to the results of Experiment 1b, because these two experiments have substantially different task demands. More specifically, if the distant attachment preference in Experiment 1b was due to the production aspects of sentence completion, then rating results from Experiment 4 should look more similar to the pattern observed in self-paced reading. Such a pattern would yield higher ratings for NP2 versus NP1 attachment in the NP2 easy condition, with less of a ratings advantage for NP1 versus NP2 attachment in the NP2 difficult condition. Regardless of the overall attachment preference, though, our modifiability account predicts that ratings should be higher for NP1 attachment in the NP2 difficult condition as compared with the NP2 easy one, yielding a reliable Modifiability × Attachment interaction.

Method

Participants

Fifty-six University of Southern California undergraduates participated for partial course credit. All were native speakers of American English, and none had participated in Experiment 1 or 3.

Materials

Stimuli were taken from the 32 English sentences used in Experiment 3. Each item consisted of the complex NP and the disambiguated modifier, resulting in the same four conditions from Experiment 3. The final modifier was underlined. An example is presented in Table 5. Four counterbalanced lists were created, with an equal number of items from each condition and each item appearing only once in each list. Items appeared in a different random order on each list. Two examples and two practice items were also composed, which preceded the experimental items.

Procedure

The materials were presented on paper. Participants were instructed to rate, on a 7-point scale, how natural the underlined modifier sounded in each sentence; a rating of 1 indicated that using the underlined modifier sounded very unnatural, and a rating of 7 indicated that using the underlined modifier sounded very natural, with a rating of 4 being neutral. The entire procedure took about 15 min.

Results and Discussion

The overall mean rating was 4.17 (SD = 1.14); means in individual conditions are shown in Figure 4. There was no reliable main effect of attachment or modifiability, but consistent with the results of Experiments 1–3, there was a significant Modifiability × Attachment interaction, $F_1(1, 55) = 29.81$, $p < .001$; $F_2(1, 31) = 14.87$, $p < .001$. Pairwise comparisons revealed that the nature of this interaction is such that ratings in the NP2 easy condition revealed no significant differences, whereas ratings were significantly higher for the NP1 attachment disambiguation in the NP2 difficult condition, $F_1(1, 55) = 14.45$, $p < .001$; $F_2(1, 31) = 20.67$, $p < .001$. In other words, there was no clear local attachment preference in the NP2 easy condition, but an NP1 attachment preference emerged in the NP2 difficult condition.

This overall pattern of data resembled the self-paced reading data from Experiment 3, in which no strong overall attachment preference emerged, and the data were inconsistent with the results of Experiment 1b, in which a strong distant attachment preference was found. These results indicate that substantial differences in interpretation can be found even among off-line tasks and further suggest that the discrepancies between the results from Experiments 1b and 3 may be due to differing task demands. Our specific hypothesis, that the production component of Experiment 1b was responsible for the overall distant attachment preference in that study, has not yet been exhaustively investigated; factors other than the production component may have affected performance in these two studies. Experiment 4 nonetheless makes the crucial point that differences between on-line and off-line results may not necessarily be due to temporally distinct processing stages (see De Vincenzi & Job, 1995) but can instead vary substantially with the experimental task.

Beyond their relevance to the present study, these results offer an important cautionary note for current sentence-processing methodology. A common practice in this field is to conduct extensive comparisons between data obtained in comprehension experiments and frequencies of usage occurring in a corpus of text (e.g., Gibson & Schütze, 1999; Spivey-Knowlton & Sedivy, 1995). The correspondence

Table 5
Sample Materials From Experiment 4

Condition	Sample sentence
NP2 easy condition	
NP1 attachment disambiguation	The puppy by a truck *with floppy ears*
NP2 attachment disambiguation	The puppy by a truck *with chipped paint*
NP2 difficult condition	
NP1 attachment disambiguation	The puppy by Jim's truck *with floppy ears*
NP2 attachment disambiguation	The puppy by Jim's truck *with chipped paint*

Note. NP1 = distant noun phrase; NP2 = local noun phrase.

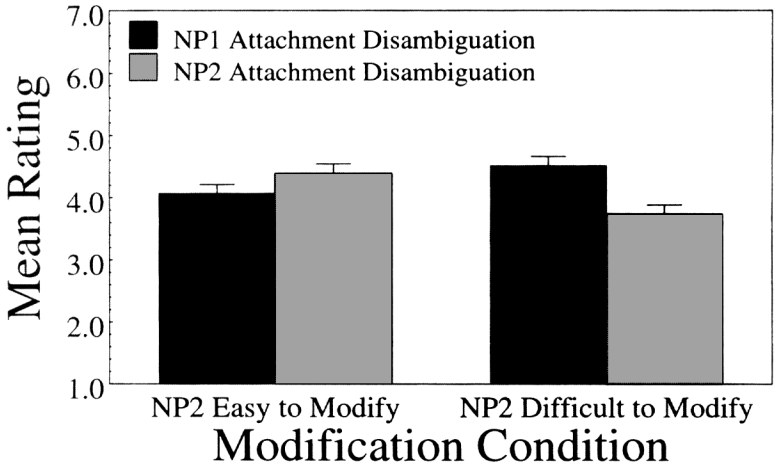

Figure 4. Mean ratings with standard error bars computed across participants for both the NP2 easy and NP2 difficult conditions from Experiment 4. A rating of 7 indicated that the modifier sounded very natural, and a rating of 1 indicated that the modifier sounded very unnatural, with 4 being neutral. NP1 = distant noun phrase; NP2 = local noun phrase.

between these two sources of data has been interpreted as support for constraint-based accounts of sentence processing (Hindle & Rooth, 1993; Spivey-Knowlton & Sedivy, 1995), and failures of correspondence between comprehension and corpus data have been interpreted as evidence against constraint-based accounts (Gibson & Schütze, 1999; Mitchell & Brysbaert, 1998). The data from the present experiments cast this debate in a new light, in that they demonstrate that comprehension data collected through different tasks may not be consistent themselves. Given this result, researchers on both sides of these issues will have to think carefully about how to interpret a correspondence, or lack thereof, between corpus data and comprehension data.

General Discussion

The experiments presented here yielded three important results. First, in both Spanish and English, and in both on- and off-line tasks, there was a robust effect of NP modifiability on interpretation of an ambiguous PP modifier: As modification to an NP became less felicitous, attachment to other NPs became more likely, even if this resulted in distant attachment. Second, there were differences between Spanish- and English-comprehenders in overall attachment preference. In the nonspecific condition, English comprehenders' on-line reading times were shorter for NP2 attachment than for NP1, whereas Spanish-speaking participants showed no clear attachment preference. This pattern indicates that the Spanish-speaking participants exhibited less of a preference for local attachment than did the English-speaking participants. Third, although all three tasks (sentence completion, self-paced reading, and naturalness rating) revealed robust modifiability effects, there was a fair amount of variation in overall attachment preferences across tasks. In English, there was a distant attachment preference for the off-line sentence completion data, whereas no clear preferences emerged in the off-line ratings task and on-line self-paced reading. This variation suggests that the nature of the task used, as well as the language being studied, should be taken into account when interpreting overall attachment patterns.

Taken together, these results suggest that cross-linguistic variation is strongly constrained by pragmatic information in both English and Spanish, but that pragmatic information is not the only constraint on attachment preferences. Thus, our results generally support constraint-based models of sentence processing (e.g., Garnsey et al., 1997; MacDonald et al., 1994; Spivey-Knowlton & Sedivy, 1995; Trueswell et al., 1994). Moreover, the finding that the referential properties of individual NPs exert a significant influence on attachment preferences poses challenges for models that emphasize structural constraints on PP modification (e.g., Fodor, 1998; Frazier & Clifton, 1996; Gibson et al., 1996; Hemforth et al., in press; Mitchell & Cuetos, 1991).

The pragmatic account we are proposing makes a strong prediction: The modifiability of an NP should affect the interpretation of modifier ambiguities in all languages. That is, we predict that pragmatic constraints of this sort are universal, and they will be evident in interpretation of all structural ambiguities in which more local constraints (such as lexical information) do not create overwhelming biases for one interpretation (Britt, 1994; MacDonald et al., 1994; Spivey & Tanenhaus, 1998). The demonstration that modifiability constrains interpretation of ambiguity in English and in Spanish is quite a long way from providing broad support for claims about the universal nature of discourse constraints, but it provides a solid step in extending the role of discourse constraints to languages other than English. In the next sections, we discuss the implications of our modifiability claims and the results of the present studies.

Cross-Linguistic Variation

As with any claim for cross-linguistic universals, the modifiability hypothesis proposed here offers no explanation

for differences among languages. There clearly are differences in attachment preferences to complex NPs in English and Spanish, and Mitchell and Brysbaert (1998) suggested that no current models of sentence processing fully explain these differences. It is true that a great deal more work remains to be done to identify all of the factors that create attachment preferences within and across languages, but we suggest that other Gricean-based constraints may offer important insights into some amount of cross-linguistic variation. Frazier (1990) and Frazier and Clifton (1996) noted that for the genitive structures originally used by Cuetos and Mitchell (1988), English has an alternative form whereas Spanish does not; specifically, both the prenominal genitive form (e.g., *the colonel's daughter*) and the prepositional genitive form (e.g., *the daughter of the colonel*) are acceptable in English, whereas only the prepositional form exists in Spanish. Frazier and Clifton (1996) proposed a Gricean account of cross-linguistic variation in this case, in which English speakers can, according to the maxim of manner (Grice, 1975), avoid ambiguity by using the prenominal form to modify *the daughter* and the prepositional form to modify *the colonel,* resulting in local attachment for both structures. Because Spanish has no such alternative structures, the same structure must be used when modifying either element, resulting in distant attachment for the modification of *the daughter.* According to this view, differences in cross-linguistic attachment preferences can stem from comprehenders' recognition of the options available to speakers and knowledge of the consequences of certain structural choices.

Although Frazier and Clifton (1996) formulated this hypothesis within the construal framework, it also fits well within a constraint-based account of sentence processing. According to this view, comprehenders are sensitive to the distributional patterns that they have encountered in their language. These distributional patterns are created by speakers and writers whose utterances are shaped by constraints on production processes, including Gricean constraints (MacDonald, 1999; Thornton, Gil, & MacDonald, 1998). In English, the availability of alternative constructions and the Gricean production constraints conspire to yield a distributional pattern in which *NP preposition NP modifier* structures are frequently used to convey the local modification interpretation, and other structures convey the meaning associated with distant modification. In Spanish, in which no alternative construction is available, the distribution of interpretations for this structure is very different. Thornton et al. (1998) argued that Spanish and English comprehenders' knowledge of distributional patterns in their language shapes their interpretation of modification ambiguities. It is clear, however, that this Gricean account alone will not account for the cross-linguistic data. Brysbaert and Mitchell (1996) ruled-out a strict Gricean account of cross-linguistic variation with evidence that Dutch speakers show an overall distant attachment preference even though the alternative prenominal genitive form is available in Dutch. In both our account and in construal, however, there is no claim that this constraint is the only one that shapes ambiguity resolution preferences; we have shown here that other factors, such as NP modifiability and even the kind of experimental task, can affect attachment preferences. Thus, we suggest that it is worthwhile to pursue a range of pragmatic factors in explaining cross-linguistic differences as well as cross-linguistic similarities. Indeed, spelling out the range of constraints that can shape cross-linguistic preferences is a challenge for all accounts of sentence processing.

Modifiability and Models of Sentence Processing

The demonstration that NP modifiability affects attachment to complex NPs has implications for the interpretation of other findings in the literature. First, previous studies of attachment to complex NPs (e.g., Cuetos & Mitchell, 1988; De Vincenzi & Job, 1995; Gibson et al., 1996; Gilboy et al., 1995) have confounded local versus distant attachment site with the amount of modification that each of the elements in the complex NPs has received. For example, in the ambiguity in (1), the first attachment site, *the daughter* is modified by the PP *of the colonel,* but the second site, *the colonel,* has no modification. On modifiability grounds, this second NP is therefore a more likely candidate for further modification than is the first NP, which has already received some modification.[2] Thus, it is unclear the extent to which attachment preferences that were observed in these prior studies should be attributed to modifiability constraints instead of, or in addition to, the structural constraints that were posited in these other studies.

Second, our investigation of modifiability has focused on noun modification ambiguities, whereas previous studies have investigated effects of similar constraints on other ambiguities (e.g., Altmann & Steedman, 1988; Britt, 1994; Spivey & Tanenhaus, 1998; Spivey-Knowlton & Sedivy, 1995). In extending the notion of modifiability to complex NP modification, we have emphasized the role of NP identifiability, but unique reference is only one part of modification that happens to be particularly relevant to NPs. There are other modification ambiguities that differ in a number of ways from the ones studied here, yet discourse-relevant constraints still appear to play an important role in their resolution. Consider, for example, ambiguities such as (4):

(4) a. Tim spied Mrs. Jones sunbathing through the curtains.
b. Tim spied Mrs. Jones sunbathing in her bikini.

In these sentences, a prepositional phrase (*through the curtains/in her bikini*) can modify either of the two verb sites (*spied/sunbathing*). Although a number of processing theo-

[2] Because of the linear ordering of the NPs, NP1 must always be modified by NP2 in experiments that investigate this ambiguity. If NP2 were to modify an earlier element in the sentence, NP1 would become unavailable for further modification. For example, in the phrase *The child near the table with red hair that was refinished last week,* the PP *with red hair* modifies *the child,* rendering the intervening site, *the table,* unavailable for attachment of the ambiguous relative clause, even though it is the only plausible site (see Radford, 1988, for discussion of crossed branches).

ries assume that these ambiguities will be handled by strict parsing algorithms such as late closure (Frazier & Rayner, 1982) or recency preference (Gibson et al., 1996), Thornton and MacDonald (1999) argued for a constraint-based approach that takes into account distributional patterns in the language and their origins in production processes. Following from work demonstrating that processing difficulty increases with phrase-length (Ferreira & Henderson, 1991, 1998; Warner & Glass, 1987), they demonstrated that the number of words separating the two sites has a substantial effect on on-line attachment preferences. Specifically, they found a local modification bias only when the second verb phrase is lengthened, as in (5):

(5) a. Tim spied his eleventh-grade chemistry teacher Mrs. Jones sunbathing through the curtains.
b. Tim spied his eleventh-grade chemistry teacher Mrs. Jones sunbathing in her bikini.

These results suggest that the distance between the sites plays an important role in the comprehension of these structures (see Fodor, 1998; Gibson, 1998, for more discussion on the role of length on processing).

MacDonald (1999) interpreted these comprehension biases as emerging from distributional patterns in the input, such that the sequence *VP1 + long VP2 + modifier* is more frequently produced with an intended local attachment interpretation than with the distant attachment interpretation. These distributional patterns, in turn, stem from constraints on production such that short phrases tend to be uttered before longer phrases when this ordering is grammatical (Hawkins, 1994; Stallings, MacDonald, & O'Seaghdha, 1998; Wasow, 1997). The sentences in (5) are counterexamples, in that a short PP *through the curtains/in her bikini* follows a longer phrase *his eleventh-grade chemistry teacher Mrs. Jones sunbathing.* This phrase order is the only permissible one when the adverbial phrase modifies the local VP *sunbathing,* but when modification of the distant site is intended, other phrase orders can convey the same meaning while not violating the preferred short-before-long phrase order (e.g., *Through the curtains, Tim spied his eleventh-grade chemistry teacher Mrs. Jones sunbathing*). Given the availability of alternative phrase orders that convey modification of the first VP while better satisfying production constraints, MacDonald (1999) argued the sequence *VP1 + long VP2 + modifier,* while technically ambiguous, is overwhelmingly used to convey local (VP2) modification in English, and that comprehenders respond to these distributional asymmetries with a strong bias to interpret sentences such as those in (5) with local modification.

This approach, in which constraints on production create distributional patterns to which comprehenders are sensitive, has the potential to unify a number of seemingly disparate findings in the study of modification ambiguities. This approach provides an explanation of how the availability of alternative structures, together with constraints on production, create different distributional patterns of utterances. The example just reviewed concerns production constraints on the ordering of phrases and the availability of an alternative phrase order for one interpretation but not the other interpretation. A second example concerns the Gricean constraints on production in English and Spanish (Frazier, 1990; Frazier & Clifton, 1996; Thornton et al., 1998). English has an alternative phrase order that better satisfies Gricean maxims, whereas Spanish does not. In both examples, production constraints and the inventory of grammatical options in the language combine to yield a particular distributional pattern. Finally, modifiability can be viewed in exactly the same way: Speakers' needs to modify NPs to satisfy Gricean constraints create distributional patterns in which some amounts of modification are much more common than others and in which the amount of modification can vary with other factors, such as position in the sentence. In all three of these examples, the link to ambiguity resolution is the same: Comprehenders are sensitive to distributional patterns in the language and interpret ambiguous structures in accord with these patterns. From the point of view of comprehension, the actual origin of the distributional pattern (e.g., from Gricean constraints, length constraints, or other constraints on production) is likely to be less important than the regularity of the patterns in guiding ambiguity resolution. Thus, comprehenders need not always calculate complex discourse constraints in order to take this distributional information into account during ambiguity resolution; rather, they may need instead to be sensitive to much more local properties such as the order and length of phrases in the sentence. This approach clearly has many aspects that are severely underexplored at the present time, but it has the potential to unify ambiguity resolution, cross-linguistic variation, and production processes in a novel way.

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Appendix A

Stimuli From Experiment 2

Items are presented as (nonspecific/specific) NP2 modification and (NP1/NP2) modifier attachment disambiguation.

1. *Los jardines de (una/mi) mansión con (árboles frondosos/ventanas coloniales) fueron fotografiados para una revista famosa.*
   The gardens of (a/my) mansion with (leafy trees/colonial windows) were photographed by a famous magazine.
2. *La propiedad de (un amigo/nuestro amigo) con (petróleo subterráneo/mucho dinero) fue destruida durante el terremoto.*
   The property of (a/our friend) with (oil/a lot of money) was destroyed during the earthquake.
3. *Los dialectos de (una/la) región con (gramáticas complicadas/muchos habitantes) fueron estudiados en los años sesenta.*
   The dialects of (a/the) region with (complicated grammar/many residents) were studied in the sixties.
4. *El maletín (de un professor/del profesor nuevo) con (base metálica/lente grandes) fue encontrado en el basurero.*
   The briefcase of (a/the new) professor with (a metal base/big glasses) was found in the trash.
5. *El restaurante de (una/la) universidad con (bebidas exóticas/profesores famosos) fue cerrado por falta de higiene.*
   The restaurant of (a/the) university with (exotic drinks/famous professors) was closed for lack of hygiene.
6. *El carro de (una/mi) amiga con (ventanas ahumadas/problemas emocionales) fue robado del estacionamiento ayer.*
   The car of (a/my) friend with (tinted windows/emotional problems) was stolen from the parking lot yesterday.
7. *La bandera de (un/su) país con (franjas horizontales/clima ideal) fue diseñada hace doscientos años.*
   The flag of (a/her) country with (horizontal stripes/ideal climate) was designed two hundred years ago.
8. *La biblioteca de (una/la) universidad con (estantes antiguos/tradición deportiva) fue construida por un arquitecto ruso.*
   The library of (a/the) university with (old bookshelves/a sports tradition) was constructed by a Russian architect.
9. *El vestido de (una/la) cantante con (piedras brillantes/voz extraordinaria) fue confeccionado por Armani.*
   The dress of (a/the) singer with (shiny stones/an extraordinary voice) was made by Armani.
10. *Las sábanas de (una/mi) cama con (diseños infantiles/resortes vencides) fueron cosidas por mi abuelita.*
    The sheets of (a/my) bed with (childish designs/worn springs) were sewn by my grandmother.
11. *Las canciones de (un/tu) disco con (estrofas interminables/portada roja) fueron grabadas en Miami.*
    The songs of (a/your) record with (unending verses/a red sleeve) were recorded in Miami.
12. *La oficina de (una/la) doctora con (muebles empotrados/acento extranjero) fue inundada por la tormenta.*
    The office of (a/the) doctor with (built-in furniture/a foreign accent) was flooded in the storm.
13. *El periódico de (una/la) ciudad con (anuncios clasificados/varios barrios) fue ganador de dos premios el año pasado.*
    The newspaper of (a/the) city with (classified advertisements/different neighborhoods) was given two awards last year.
14. *La canción (de un cantante/del cantante famoso) con (melodías extranjeras/mucho talento) fue nominada para un premio.*
    The song of (a singer/the famous singer) with (foreign melodies/much talent) was nominated for an award.
15. *Las calles de (un/tu) barrio con (nombres indígenas/periódico propio) fueron reconstruidas después de la guerra.*
    The streets of (a/your) neighborhood with (Indian names/its own newspaper) were reconstructed after the war.
16. *El zoológico (de un millonario/del millonario eccéntrico) con (animales exóticos/cien limosinas) fue inaugurado el sábado pasado.*
    The zoo of (a/the eccentric) millionaire with (exotic animals/a hundred limousines) was inaugurated last Saturday.
17. *La computadora de (una/mi) oficina con (pantalla gigante/pocos empleados) fue comprada para agilizar el trabajo.*
    The computer of (an/my) office with (a giant screen/few employees) was bought to speed up work.
18. *La guitarra eléctrica (de un músico/del músico loco) con (cuerdas metálicas/pelo largo) fue confiscada por la policía.*
    The electric guitar of (a/the crazy musician) with (metal strings/long hair) was confiscated by the police.
19. *La policía de (una/mi) ciudad con (oficiales amables/mucho crimen) fue creada por la nueva gobernadora.*
    The police force of (the/my) city with (friendly officers/a lot of crime) was created by the new governer.
20. *Los habitantes (de un país/del país vecino) con (familia extranjera/guerra civil) fueron exiliados sin problemas.*
    The residents of (a country/the neighboring country) with (foreign families/civil war) were exiled without problems.
21. *Los indígenas de (una/la) selva con (culturas aborígenes/tala forestal) fueron estudiados por científicos de las Naciones Unidas.*
    The natives of (a/the) forest with (aboriginal cultures/clear-cutting) were studied by scientists of the United Nations.
22. *El programa (de un animador/del animador Chileno) con*

(concursos fáciles/muchas canas) fue seguido por poca gente durante el mundial.
The show of (a host/the Chilean host) with (easy contests/a lot of gray hair) was watched by few people worldwide.

23. *El carro (de un director/del director técnico) con (parachoques neón/mal carácter) fue estacionado al final de la calle.*
The car of (a director/the technical director) with (neon underneath/a bad temper) was parked at the end of the street.
24. *Las cucarachas de (una/la) ciudad con (alas gigantes/basureros subterráneos) fueron matadas una por una.*
The roaches of (a/the) city with (giant wings/sewers) were killed one by one.
25. *Los trabajadores de (una/la) fábrica con (sueldos miserables/máquinas nuevas) fueron despedidos al final del mes.*
The workers of (a/the) factory with (miserable wages/new machines) were fired at the end of the month.
26. *Las tribus (de un desierto/del desierto africano) con (costumbres nómadas/tierra infértil) fueron otorgadas territorios propios.*
The tribes of (a desert/the African desert) with (nomadic customs/infertal land) were given their own land.
27. *El espectáculo de (una/la) bailarina con (música alegra/cuerpo monumental) fue presenciado por miles de personas.*
The performance of (a/the) dancer with (lively music/a perfect body) was watched by thousands of people.
28. *El director de (una/la) escuela con (buenas intenciones/muchos alumnos) fue llamado a una reunión por algunos padres preocupados.*
The director of (a/the) school with (good intentions/many students) was called to a meeting by worried parents.

Appendix B

Mean Unadjusted RTs (in Milliseconds) by Condition and Critical Word Position and Results From ANOVAs From Experiment 2

Condition	Word position					
	1	2	3	4	5	6
	Mean unadjusted RTs					
NP2 easy condition						
NP1 modification	415	446	502	458	529	472
NP2 modification	394	433	492	457	509	465
NP2 difficult condition						
NP1 modification	402	460	521	465	509	477
NP2 modification	402	449	562	481	517	476
	Results of ANOVAs					
Modifiability						
F_1	0.13	2.86	8.40*	3.47	0.32	1.73
F_2	0.05	2.03	3.65	3.73	0.37	0.97
Attachment						
F_1	2.56	2.14	1.59	0.87	0.25	0.31
F_2	1.32	1.27	0.36	0.29	1.06	0.58
Interaction						
F_1	3.25	0.01	6.30*	1.40	1.65	0.15
F_2	3.13	0.02	4.77*	0.96	1.29	0.39

Note. Degrees of freedom for all F_1s = (1, 39) and for F_2s = (1, 27). RT = reading time; ANOVA = analysis of variance; NP1 = distant noun phrase; NP2 = local noun phrase.
*$p < .05$.

(Appendix C follows)

Appendix C

Stimuli From Experiment 3

Items are presented as (nonspecific/specific) NP2 modification and (NP1/NP2) modifier attachment disambiguation.

1. The computer down (the only hall/the front hall) with (expanded memory/drinking fountains) was used by the programmer.
2. The book in (the only library/the main library) with (ripped pages/card catalogs) was read by the researcher.
3. The vagrant near (the house/Mary's house) with (beer breath/storm windows) was found by the police.
4. The puppy by (a truck/Jim's truck) with (floppy ears/chipped paint) was loved by her owner.
5. The park behind (the other building/the main building) with (baseball diamonds/freight elevators) was owned by the mayor.
6. The album near (the stereo/Bob's stereo) with (soulful ballads/volume display) was recorded by the singer.
7. The man on (the crutches/his crutches) with (sore legs/rubber tips) was hit by the train.
8. The fence around (the yard/Ted's yard) with (rusted gates/maple trees) was built by my father.
9. The flowers in (the oldest vase/the priceless vase) with (thorny stems/porcelain legs) were planted by the gardener.
10. The bed in (the French castle/the King's castle) with (hand-sewn quilts/torture chambers) was carved by the prince.
11. The bush by (the tallest tower/the cemetery tower) with (poison berries/steep stairs) was burned by the fire.
12. The city by (the deepest river/the western river) with (towering sky-scrapers/white-water rafting) was destroyed by the flood.
13. The lion in (the only zoo/the city zoo) with (matted fur/bicycle ramps) was trained by the circus.
14. The desk at (the remodeled headquarters/the company's headquarters) with (scratched sides/tennis courts) was used by the broker.
15. The lawyer in (the firm/our firm) with (fuzzy eyebrows/nationwide offices) was sued by the client.
16. The number on (the calculator/my calculator) with (twelve digits/faulty wiring) was computed by the scientist.
17. The motorbike by (the toolshed/our toolshed) with (engine problems/window shades) was wrecked by the boy.
18. The plumber by (an enamel sink/our kitchen sink) with (hairy arms/clogged spouts) was hired by my wife.
19. The boxer in (the sauna/his sauna) with (bloodied knuckles/wooden paneling) was defeated by the challenger.
20. The teacher on (the school bus/the morning bus) with (gaudy jewelry/radial tires) was attacked by the principal.
21. The biologist in (the lab/his lab) with (beady eyes/open windows) was surprised by the result.
22. The criminal in (some jail/county jail) with (striped clothing/guard towers) was arrested by the detective.
23. The athlete in (the only local gym/the high school gym) with (bulging muscles/vaulted ceilings) was recruited by the promoter.
24. The artist in (the studio/her studio) with (radical ideas/brick walls) was embarrassed by the incident.
25. The glass by (a small coffeepot/the office coffeepot) with (crystal etchings/automatic shutoff) was broken by the sleeper.
26. The professor of (the class/our class) with (myopic vision/weekly readings) was bothered by the students.
27. The horse in (a country stable/the Jensens' stable) with (painful blisters/overhead beams) was ridden by the jockey.
28. The diplomat in (a holiday parade/the mayor's parade) with (wool gloves/ticker tape) was admired by the viewers.
29. The tenant in (an uptown apartment/the upstairs apartment) with (overdue payments/termite damage) was evicted by the owner.
30. The music in (an unpopular club/the club next-door) with (hypnotic rhythm/free admission) was played by the D.J.
31. The socks in (a run-down laundromat/the rural laundromat) with (frayed toes/vending machines) were left by the brother.
32. The tie in (an unpublished picture/my senior picture) with (polka dots/grainy resolution) was worn by my uncle.

Appendix D

Mean Unadjusted RTs (in Milliseconds) by Condition and Critical Word Position and Results From ANOVAs From Experiment 3

Condition	Word position					
	1	2	3	4	5	6
	Mean unadjusted RTs					
NP2 easy condition						
NP1 modification	380	397	443	383	375	363
NP2 modification	375	382	412	371	359	355
NP2 difficult condition						
NP1 modification	379	379	434	403	388	358
NP2 modification	373	376	439	392	383	353
	Results of ANOVAs					
Modifiability						
F_1	0.02	4.34*	3.12	9.06*	13.84*	0.81
F_2	0.02	2.77	2.32	11.83*	15.21*	1.27
Attachment						
F_1	1.03	1.02	2.10	0.04	5.17*	0.03
F_2	0.55	1.22	1.66	0.01	3.79	0.11
Interaction						
F_1	0.12	0.54	6.15*	4.43*	0.42	1.69
F_2	0.00	0.13	6.12*	4.33*	0.71	0.63

Note. Degrees of freedom for all F_1s = (1, 47) and for F_2s = (1, 31). RT = reading time; ANOVA = analysis of variance; NP1 = distant noun phrase; NP2 = local noun phrase.
*$p < .05$.

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