Recency and lexical preferences in Spanish

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One experiment provided evidence in support of Gibson, Pearlmutter, Canseco-Gonzalez, and Hickok's (1996) claim that a recency preference applies to Spanish relative clause attachments, contrary to the claim made by Cuetos and Mitchell (1988). Spanish speakers read stimuli involving either two or three potential attachment sites in which the same lexical content of the two-site conditions appeared in a different structural configuration in the three-site conditions. High attachment was easier than low attachment when only two sites were present, but low attachment was preferred over high attachment, which was in turn preferred over middle attachment, when three sites were present. The experiment replicated earlier results and showed that (1) attachment preferences are determined in part by a preference to attach recently/low, and (2) lexical biases are insufficient to explain attachment preferences.

Recent debate about the properties of the human sentence processor has focused both on the purported universality, or cross-linguistic applicability, of various parsing principles (e.g., Brysbaert & Mitchell, 1996; Cuetos & Mitchell, 1988; Frazier, 1987a, 1987b; Mitchell & Cuetos, 1991; Schriefers, Friederici, & Kuhn, 1995) and on the degree to which such principles might be replaced by lexically and contextually determined preferences (e.g., Boland, Tanenhaus, Garnsey, & Carlson, 1995; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994). Although some of the proposals that are intended to account for evidence about lexical and contextual effects also have implications for universality issues (e.g., Tabor, Juliano, & Tanenhaus, 1997; cf. Frazier, 1995), the majority of the work examining one issue has not directly examined the other (cf. Schriefers et al., 1995).

One proposed universal parsing principle that has received recent attention with respect to the universality issue is Frazier's (1978, 1987a) late closure principle (see also Kimball's, 1973, right association and Gibson's, 1991, recency preference). Late closure specifies that the parser should attach new material to the clause or phrase currently being processed, when grammatically permissible. This principle accounts for the preference in Example 1a to attach *yesterday* to the recently processed verb phrase (VP) *died* rather than to the earlier VP *said*, and for the preference in Example 1b to interpret the noun phrase (NP) *a mile* as the direct object of the current VP (headed by *jogs*), instead of as the subject of the upcoming matrix clause. In Example 1b, the result of the late closure preference is measurable difficulty (Frazier & Rayner, 1982) when *a mile* must be reanalyzed as the matrix clause subject.

(1) a. John said Bill died yesterday.
    b. Since Jay always jogs a mile seems light work.

Late closure intuitively applies in English, but Cuetos and Mitchell (1988; Mitchell & Cuetos, 1991; Mitchell, Cuetos, & Zagar, 1990) argued that a preference for attachments to recent over nonrecent material (as in Example 1a) was not universal. For Spanish, in particular, they showed that comprehenders preferred high (less recent) attachment in constructions like Example 2a, where the relative clause (RC) *que tuvo el accidente* (*who had had the accident*) can either attach high to *hija* (*daughter*) or low to *coronel* (*colonel*). English speakers preferred low attachment for corresponding ambiguous English stimuli, as in Example 2b.

(2) a. El periodista entrevistó a la hija del coronel que
        tuvo el accidente.
    b. The journalist interviewed the daughter of the
        colonel who had had the accident.

Mitchell and Cuetos (1991; Cuetos & Mitchell, 1988) provided on-line evidence for a Spanish high-attachment preference by using disambiguated versions of the construction in Example 2a, as shown in Example 3. Spanish comprehenders read the prepositional phrase *con su marido* (*with her husband*) more slowly in Example 3a than in Example 3b, because the RC *que estaba en el balcón* (*who was on the balcony*) is forced to attach to the low site *actriz* (*actress*) in Example 3a, whereas it attaches to the high site *criada* (*servant*$_{FEM}$) in Example 3b.

(3) a. Alguien disparó contra el criado de la actriz que
        estaba en el balcón con su marido.
        "Someone shot the servant$_{MASC}$ of the actress who
        was on the balcony with her husband."
    b. Alguien disparó contra el criada del actor que
        estaba en el balcón con su marido.
        "Someone shot the servant$_{FEM}$ of the actor who
        was on the balcony with her husband."

More recent examinations of the ambiguity in Examples 2 and 3 have replicated these findings (e.g., Carreiras & Clifton, 1993, 1998; Gilboy, Sopena, Clifton, & Frazier, 1995), and the preference for nonrecent attachment in this construction has also been found in German (Hemforth, Konieczny, & Scheepers, 1997) and Dutch (Brysbaert & Mitchell, 1996), whereas Italian speakers appear to show the same low-attachment preference as English speakers (de Vincenzi & Job, 1995). Because of the variation across languages, Mitchell and Cuetos (1991; see also Cuetos, Mitchell, & Corley, 1996) proposed the *tuning hypothesis*: that parsing preferences are tuned on a construction-by-construction basis within a language, with comprehenders attending to the relative frequencies of the alternatives with which an ambiguity is resolved. On this proposal, comprehenders' preferences for recent or nonrecent attachments in a language result from the history of the comprehenders' exposure to the language and specifically to similar constructions in the language, rather than from any structurally defined simplicity or ease-of-processing metric like late closure.

Contrary to Mitchell and Cuetos' (1991) claim, however, is evidence presented by Gibson, Pearlmutter, Canseco-Gonzalez, and Hickok (1996) that late closure (or a similar recency property) does apply in Spanish RC attachments. They measured reading times using an on-line grammaticality judgment task with items like those in Example 4, in both Spanish and English.

(4) a. la lámpara cerca de la pintura de la casa que fue
        dañada en la inundación
    b. the lamp near the painting of the house that was
        damaged in the flood

Whereas there are only two possible attachment sites for the RC in Example 2, Example 4 contains three possible sites (*lámpara*, *pintura*, *casa*; *lamp*, *painting*, *house*) for the RC *que fue dañada en la inundación* (*that was damaged in the flood*). This difference resulted in a change in the cross-linguistic pattern: Gibson, Pearlmutter, et al. (1996) found that both Spanish and English readers preferred attachment of the RC to the lowest site (*casa*; *house*), followed by attachment to the highest site (*lámpara*; *lamp*), with middle attachments (to *pintura*; *painting*) being the most difficult. Thus when only two attachment sites for the RC were present, in Cuetos and Mitchell (1988), Spanish and English differed, but when a third site was also present, comprehenders in the two languages showed the same pattern, preferring to attach to the most local site.

In order to account for the differing cross-linguistic preferences in two- and three-site ambiguities, Gibson, Pearlmutter, et al. (1996) proposed two principles. One of these, recency (closely related to late closure), applied uniformly across languages and specified an increasing cost associated with increasingly distant attachments. The second principle, predicate proximity, specified a fixed cost associated with attachments that were not as close as possible to a predicate phrase (typically a VP). Furthermore, they hypothesized that the relative strength of predicate proximity varied across languages, and that it was weak in English but strong in Spanish. (See the Discussion for more detail on this hypothesis.) As a result, in English, recency dominates even for 2NP ambiguities, and becomes stronger as the number of sites increases, because more distant attachments become increasingly more costly by recency, whereas predicate proximity is constant over distance. In Spanish, however, predicate proximity is strong enough to dominate in 2NP ambiguities, even though recency dominates for more extended ambiguities (three or more sites).

Although Gibson, Pearlmutter, et al.'s (1996) proposal provides one possible account of the RC attachment data, there are other ways to interpret the results. In particular, recent constraint-based lexicalist theories (see, e.g., MacDonald et al., 1994; Trueswell & Tanenhaus, 1994) have argued that attachment preferences are determined by a combination of lexically based frequency biases and broader contextual biases such as plausibility, rather than structurally based principles. Because the stimuli in the 2NP and 3NP studies differed in lexical content and were not independently controlled for plausibility, these factors might be able to explain the preferences in both the 2NP and 3NP structures. Related accounts have been proposed for similar ambiguities, involving attachment of a prepositional phrase (PP) (instead of an RC) either to multiple possible NP sites (Gibson & Pearlmutter, 1994; MacDonald & Thornton, 1996) or to a VP or an NP site (Schütze & Gibson, in press; Spivey-Knowlton & Sedivy, 1995; Taraban & McClelland, 1988; cf. Clifton, Speer, & Abney, 1991; Rayner, Carlson, & Frazier, 1983). On some lexically based approaches, PP and RC attachments can be treated similarly, and thus just as some nouns are more likely than others to take a modifier with

a particular preposition (e.g., *the book about . . .* vs. *the brick about . . .*), nouns might differ in their frequency of modification by an RC. If this determines attachment preferences (i.e., RCs prefer to attach to whichever noun site is most frequently modified), then RC attachment preferences should follow particular nouns, regardless of the nouns' relative structural positions.

The present experiment examines this possibility in Spanish using 2NP and 3NP constructions, as in earlier work. However, the specific NPs used for the two sites available in the 2NP construction were also used as the middle and low attachment sites in the 3NP construction, and the same RC was used for all conditions. Thus if preferences follow the particular nouns, the high and low sites in the 2NP construction should show the same pattern as the middle and low sites in the 3NP construction. If instead a non–lexically based principle determines preferences, the results should replicate the Spanish pattern in the literature: For 2NP constructions, the high site should be preferred, whereas for 3NP constructions, the low site should be preferred, followed by the high site and then the middle site.

Constraint-based lexicalist approaches (and others) also raise the possibility that plausibility could determine attachment preferences. In cases of ambiguous RC attachment, attachment of the RC to one site might create a more plausible interpretation than attachment of the RC to another site. For example, in *the lamp near the painting that was flickering in the window*, the lamp is a more plausible subject of *was flickering* than is the painting. Although the RCs in previous studies examining both 2NP and 3NP constructions were designed to be plausible modifiers prior to the disambiguating region, subtle plausibility differences among the different attachments might nevertheless have determined the pattern of results. If such plausibility differences were responsible for the earlier patterns, then the same set of predictions should hold as for lexically based biases: Attachment preferences should follow the particular nouns, because the attaching RC is the same across the 2NP and 3NP constructions.[1]

In addition to testing lexical-bias and plausibility predictions, the present experiment allowed us to determine whether three other potentially important differences between the earlier 2NP and 3NP experiments could explain the different patterns of results. The first of these is that the type of preposition used to link the attachment sites differed across the 2NP and 3NP experiments. Gilboy et al. (1995) showed in a forced-choice questionnaire study that the nature of the linking preposition for 2NP constructions influences attachment preferences in such a way that high attachment is easier when a thematically vacuous preposition like *de* (*of*) intervenes between the two sites than when a preposition like *con* (*with*) intervenes, which assigns a thematic role independent of the head noun it follows (see also de Vincenzi & Job, 1995, for similar results in Italian). Cuetos and Mitchell (1988) and most of the other studies examining 2NP constructions used a form of *de* (as in Example 2a: *la hija del coronel*)

to link the NPs, whereas Gibson, Pearlmutter, et al. (1996) used a variety of prepositions, the majority of which were locatives (e.g., *cerca de* [*near*], as in Example 4a) or specified other adjunct relationships assigning thematic roles independent of their preceding head nouns, including the preposition *con* (*with*). Hence Gibson, Pearlmutter, et al. may have found a low-attachment preference because they used a larger proportion of thematic-role-assigning prepositions than were used in the 2NP experiments (see Cuetos et al., 1996, for discussion). The present experiment controlled for this possibility by always using the preposition *de* to link the attachment sites.

A second potentially confounding difference between the 2NP and 3NP Spanish preference patterns is that the Gibson, Pearlmutter, et al. (1996) 3NP study used a word-by-word timed ungrammaticality judgment task, whereas studies of the 2NP ambiguity used either off-line judgments of ambiguous stimuli or region-by-region self-paced reading (e.g., the RC might be presented all at once). Thus one possibility is that the on-line ungrammaticality judgment task artificially inflates low-attachment preferences (e.g., because processing resources normally devoted to maintaining the availability of higher sites in memory are instead required to perform the additional judgment task). Cuetos et al. (1996; cf. Gilboy & Sopena, 1996) discussed related concerns. The present study used word-by-word self-paced reading, with no grammaticality judgment component, for both 2NP and 3NP stimuli.

A third difference between Gibson, Pearlmutter, et al. (1996) and all of the 2NP ambiguity studies is that Gibson, Pearlmutter, et al. used complex NP fragments (as in Example 4) rather than complete sentences (as in Examples 2a and 3). Gibson, Pearlmutter, et al. effectively assumed that readers would treat the fragments as subjects of sentences, although a matrix verb was never presented. In the 2NP ambiguity studies, however, the first of the two sites was a direct or indirect object, and thus the entire complex NP followed the sentence's matrix verb. If maintaining an NP structure (e.g., a subject NP) in working memory prior to encountering a licensing verb involves some cost (Gibson, 1991), then the fact that Gibson, Pearlmutter, et al.'s NPs occurred without verbs might have created an additional bias to attach to very recently processed material. The complex NPs in the present experiment were all either direct or indirect objects, so a replication of the Gibson, Pearlmutter, et al. result would indicate that the subject- versus object-position placement of the complex NP does not interact with attachment preferences within the NP.

METHOD

Participants

Twenty-five students from the Boston academic community participated for class credit or for $5. One of these participants was excluded because of poor comprehension question performance on the filler stimuli (76%; all other participants were at 82% or better, $M = 92\%$). All participants were native Spanish speakers, from

Spain (8 participants), Mexico (3), the Canary Islands (2), El Salvador (2), Peru (2), the United States (2), Colombia, Cuba, the Dominican Republic, Nicaragua, or Venezuela.

Materials

Thirty stimulus sentences were constructed, each with five versions. An example stimulus item is shown in Example 5, and the full set of items is listed in the Appendix. All stimuli began with a subject NP (*el astrónomo* [*the astronomer*] in Example 5) and a matrix verb (*predijo* [*predicted*]). Following the verb were a series of NPs and PPs that contained potential attachment sites for the concluding RC modifier (*que se observó desde el satélite* [*that was observed from the satellite*]). The stimuli contained either two (Examples 5a and 5b) or three (Examples 5c–5e) potential NP attachment sites, which were linked by the appropriate form of the preposition *de* (*of*). The three-site versions were always created from the two-site versions by inserting an additional NP site (*el/los cambio*[*s*]) between the verb and the other two NP sites, so that the highest site (*la*[*s*] *órbita*[*s*]) in the two-site versions was the middle site in the three-site versions. The stimuli were disambiguated by number agreement: The number marking on the verb in the RC (half singular, half plural) always matched exactly one of the potential NP attachment sites. Thus Example 5a requires high attachment to *órbita*, 5b requires low attachment to *planeta*, 5c requires high attachment to *cambio*, 5d requires middle attachment to *órbita*, and 5e requires low attachment to *planeta*.

> (5) a. El astrónomo predijo la órbita de los planetas que se observó desde el satélite.
> b. El astrónomo predijo las órbitas del planeta que se observó desde el satélite.
> c. El astrónomo predijo el cambio de las órbitas de los planetas que se observó desde el satélite.
> d. El astrónomo predijo los cambios de la órbita de los planetas que se observó desde el satélite.
> e. El astrónomo predijo los cambios de las órbitas del planeta que se observó desde el satélite.
> "The astronomer predicted (the change[s] of) the orbit(s) of the planet(s) that was observed from the satellite."

In addition to the experimental stimuli, 70 fillers and nine practice items with a variety of structures were also constructed. Yes/no comprehension questions were written for all stimuli as well.

The experimental stimuli and fillers were combined to form five 100-item lists. The experimental stimuli were counterbalanced across lists, so that each version of an experimental stimulus item appeared in exactly one list, and each list contained the same number of items in each condition. Each participant saw exactly one list.

Apparatus and Procedure

Two Apple Macintosh computers (a Centris 610 and a Quadra 950) were used to present stimuli and collect responses. Each participant read the practice items, followed by the items in one of the lists in a random order. All instructions and materials were in Spanish. All stimuli fit on one or two display lines, and for the experimental stimuli, all material from the beginning of the sentence through the disambiguating verb and the three following words was presented on the first line of the display.

The stimuli were presented using a noncumulative word-by-word self-paced moving window paradigm (Just, Carpenter, & Woolley, 1982). At the beginning of a trial, an item was displayed on the screen with all nonspace characters replaced by dashes. When the participant pressed the space bar, the first word of the item was displayed, replacing the corresponding dashes. When the participant pressed the space bar a second time, the first word reverted to dashes, and the second word was displayed in place of the appropriate dashes. Each subsequent press of the space bar revealed the next word and removed the previous word. Pressing the space bar on the last word of the item caused the item to be replaced by its yes/no comprehension question, which the participant answered by pressing one of two keys above the space bar on the keyboard. The computer recorded the time between each buttonpress as well as the comprehension question response and presented feedback about the participant's answer to the question. Most participants completed the experiment in approximately 35 min.

Norming Survey

For the middle site to be available for attachment of the RC, the second PP (*de los planetas* in Examples 5c–5e) must attach to the immediately preceding NP (*órbita*). If instead the second PP attaches to the high site (*cambio*), then attachment of the RC to the middle site is blocked because it would require a structure with crossed branches. The items were constructed so that the second PP was semantically biased to attach to the immediately preceding NP. So, for example, in Examples 5c–5e, *de los planetas* is much more likely to modify *órbita* than *cambio*. Furthermore, the second preposition was always *de* (*of*), and in English, PPs headed by *of* overwhelmingly prefer to attach to the immediately preceding NP (Hindle & Rooth, 1993). If the same preference holds in Spanish, then the second PPs in our stimuli should also strongly prefer to attach to the immediately preceding NP. In order to confirm the local attachment bias of the second PP, we conducted a norming survey following Gibson, Pearlmutter, et al. (1996) in which participants were asked to judge whether the second PP modified the high site or the middle site, using stimuli like Example 6.

> (6) El astrónomo predijo el cambio de la órbita del planeta.
> "The astronomer predicted the change of the orbit of the planet."

Each of the 30 norming stimuli was constructed from one of the main experimental stimulus items by removing the RC and making the three attachment sites singular. For each item, the alternative attachment sites (*el cambio*, *la órbita*) were listed below the item. Two versions of each item were constructed, varying the order of presentation of the attachment sites. The 30 norming stimuli were pseudorandomly mixed with 72 filler items to form two counterbalanced lists, each of which contained one version of each item. Fifteen native Spanish-speaking participants from the MIT community, none of whom took part in the main experiment, each completed one or the other of the two lists. The overall preference for attachment of the second PP to the immediately preceding NP (the middle NP) was 93% (*SD* = 9.7), with item means ranging from 80% to 100%. The attachment preference for each item is shown in the Appendix.

Because not every item had a 100% local attachment of the second PP, it was possible that difficulty with middle attachment could arise from the small percentage of ungrammatical instances in which the second PP attached to the high site. To ensure that our results were not due to the small percentage of cases in which middle attachment was ungrammatical, we conducted the analyses including all items except the three with middle NP preference less than 85%. The pattern of results for all of these analyses was numerically identical to that reported below, and none of the differences involving the middle attachment condition varied by more than 2 msec from those reported below. Thus the results were not due to possible ungrammaticality of the middle site attachment.

RESULTS

As a result of an error in constructing the stimulus lists, one item (marked with an asterisk in the Appendix) was ungrammatical in its 3NP middle attachment version, and this item was therefore excluded from all analyses.

Table 1
Comprehension Question Performance

Number of Sites	Attachment	% Correct	SE
Two	High	79	3.9
	Low	72	4.5
Three	High	76	2.7
	Middle	77	2.9
	Low	76	2.8

Note—*SE*s were computed over participant means.

Comprehension question performance by condition is shown in Table 1. With only two NP attachment sites, performance was marginally better, by participants only, for high attachment than for low attachment [$F_1(1,23) = 3.43$, $MS_e = 259$, $p < .10$; $F_2(1,28) = 1.06$, $MS_e = 524$, $p > .30$]. Performance did not differ among the 3NP conditions ($Fs < 1$).

To remove noise resulting from differences in participants' overall reading times and differences in participants' sensitivity to word length, a regression equation predicting reading time from word length was constructed for each participant, using all filler and experimental items (Ferreira & Clifton, 1986; see Trueswell, Tanenhaus, & Garnsey, 1994, for discussion). At each word position, the reading time predicted by the participant's regression equation was subtracted from the actual measured reading time to obtain a residual reading time. Thus each par-

ticipant's mean reading time per word across the entire experiment was transformed to a 0-msec residual reading time, and negative residual times indicate faster-than-average times, whereas positive residual times indicate slower-than-average times.

For the purpose of analysis, we defined the three-word region beginning with the number-marked verb in the RC as the disambiguating region for the stimuli, and this is the region for which we report results. Residual reading times beyond 2.5 *SD* from the corresponding condition mean in this region were excluded, affecting less than 2.5% of the data, and all analyses were conducted on the resulting data set. Separate analyses were conducted treating participants (F_1) and items (F_2) as random factors (Clark, 1973).

Figure 1 shows the disambiguating region residual reading time grand means by condition. The corresponding non-length-corrected reading times are reported below in the text; like the residual times, these were trimmed at 2.5 *SD* (affecting less than 2.5% of the data).

A one-way analysis of variance (ANOVA) including all five conditions at the disambiguating region revealed significant differences [$F_1(4,92) = 5.51$, $MS_e = 2,096$, $p < .01$; $F_2(4,112) = 4.97$, $MS_e = 2,570$, $p < .01$], and individual difference tests supported these findings:[2] Of the two 2NP conditions, high attachments (449 msec) were faster than low attachments [478 msec; $F_1(1,92) =$
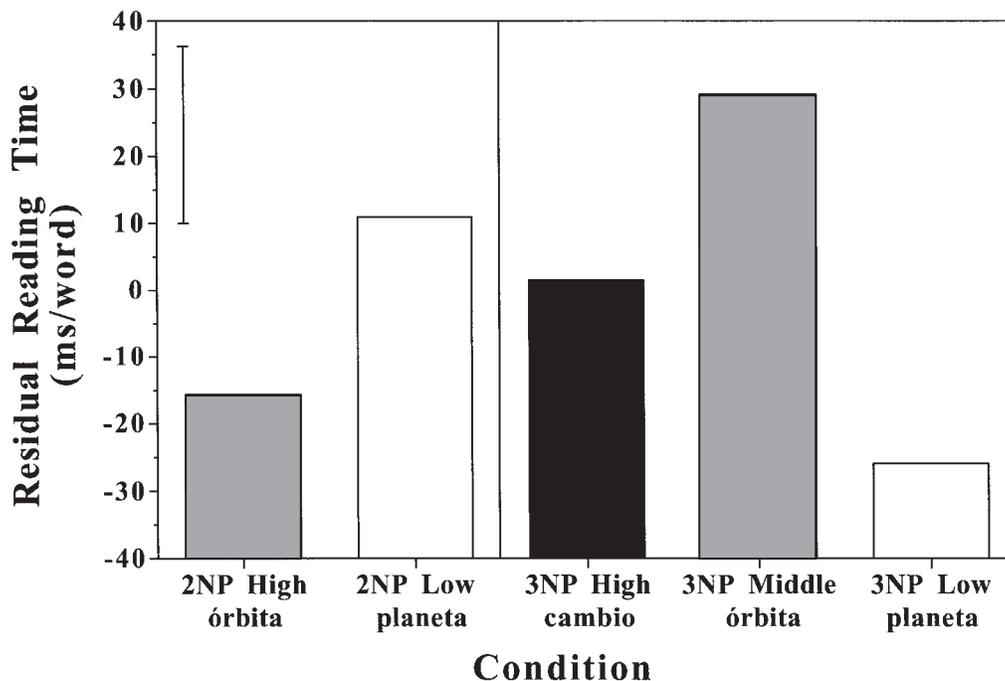

Figure 1. Residual reading time by condition in the disambiguating region (e.g., *observó desde el*). The example text shown for each condition (e.g., *órbita*) is the site to which the relative clause attaches in that condition. Identically colored bars indicate attachment to lexically identical sites. The error bar shows the 95% confidence interval (computed over participants) for the comparison between any two condition means (Loftus & Masson, 1994). NP, noun phrase.

4.57, $p < .05$; $F_2(1,112) = 3.93$, $p < .05$]. Among the three 3NP conditions, low attachments (445 msec) were fastest [vs. middle attachments, 495 msec, $F_1(1,92) = 17.29$, $p < .001$; $F_2(1,112) = 15.54$, $p < .001$; vs. high attachments, 467 msec, $F_1(1,92) = 4.14$, $p < .05$; $F_2(1,112) = 4.66$, $p < .05$], and high attachments were faster than middle attachments [$F_1(1,92) = 4.50$, $p < .05$; $F_2(1,112) = 3.18$, $p < .10$], although the latter comparison was marginal by items.

To examine potential effects of plausibility and lexically based biases, a 2 (number of sites) × 2 (lowest two sites) ANOVA was conducted to examine how preferences changed for the two lowest sites (the gray bars and the white bars in Figure 1) when they were the only two (the left two bars in the figure; high and low attachment in the 2NP conditions) relative to when they were preceded by a higher site (the right two bars in the figure; middle and low attachment in the 3NP conditions). This analysis revealed an interaction between number of sites and relative position [$F_1(1,23) = 15.44$, $MS_e = 2,691$, $p < .01$; $F_2(1,28) = 22.65$, $MS_e = 1,993$, $p < .001$] in that the higher of the two sites (e.g., *órbita*) was an easier target for attachment than the lower of the two (e.g., *planeta*) when only two sites were present; but the same lexical item (*órbita*) was a much poorer target for attachment than the lower one (*planeta*) when an even higher site was available (*cambio*) in the 3NP cases. Because the lexical content of the sites involved (and of the RC) was the same across the 2NP and 3NP conditions, the interaction indicates that the structural position of the potential attachment site must have been playing a role in determining attachment difficulty.

DISCUSSION

The results of this experiment clearly replicated those of earlier studies examining 2NP and 3NP RC attachments in Spanish: For 2NP constructions, high attachment was preferred, but for 3NP constructions, low attachment was preferred, with high attachment next. Because the same lexical items were used as the two lowest sites in each of the 2NP and 3NP constructions, and because the relative preference for these two sites changed when a third (high) site was added, neither lexical biases associated with particular nouns nor the relative plausibility of the different RC attachments can account for the pattern of effects.[3] The study also ruled out three additional previously confounding factors as possible explanations for the difference between 2NP and 3NP attachment preference patterns in Spanish: differences in (1) linking prepositions, (2) the task, and (3) the position (subject vs. object) of the ambiguity in the sentence. Although any of these factors (including lexical biases and plausibility) might influence attachment preferences, none of them is sufficient to explain the present results. The difference between the 2NP and 3NP attachment preferences thus appears to be due to an independent general bias favoring low attachment in 3NP ambiguities and high attachment in 2NP ambiguities.

One possible account of the Spanish RC attachment preference pattern is the two-factor theory proposed by Gibson, Pearlmutter, et al. (1996). The first factor in this theory is the recency preference principle, which states that incoming lexical items are preferentially attached to structures built more recently. Gibson, Pearlmutter, et al. defined recency as a function of the number of intervening potential attachment sites. However, Gibson (1998) argued that recency could be defined more generally as a function of the number of new discourse predicates and referents (Heim, 1982; Kamp, 1981) intervening between the attachment site and the attaching category. Either of these formulations accounts for the current data, but the discourse structure proposal also correctly predicts that increasing the distance between the head noun of a subject NP and its verb increases reading time at the verb (Gibson, 1998). Because the Gibson, Pearlmutter, et al. formulation attends only to intervening attachment sites and not any other intervening material, it cannot capture such effects.

A second advantage of the Gibson (1998) discourse-based formulation of recency is that it provides an account of Gilboy et al.'s (1995) observation that the thematic content of the linking preposition in 2NP RC attachment constructions can influence attachment preferences. In particular, they found a stronger tendency to attach high in 2NP constructions when the linking preposition was *de* (*of*), which did not assign an independent thematic role in their stimuli, as opposed to *con* (*with*), which did assign an independent role. The preference difference follows from the Gibson (1998) discourse-based proposal because prepositions like *de* do not introduce a new predicate into the discourse structure, whereas prepositions like *con* do and thus increase the distance between the two NP attachment sites. This makes the higher site less accessible (less recent) and makes high attachment more difficult. See Gibson (1998) for additional evidence supporting a discourse-structure-based formulation of recency.

The second component of the two-factor theory proposed by Gibson, Pearlmutter, et al. (1996) is more speculative: the predicate proximity principle, which states that attachment as close as possible to the head of a predicate phrase (typically a verb phrase) is preferred. The rationale given for this proposal was that because all grammatical utterances have a predicate (verb) at their core, a verb and its arguments are kept in memory more strongly than other categories. In order to account for the cross-linguistic difference between English and Spanish, Gibson, Pearlmutter, et al. hypothesized that the relative strength of predicate proximity was determined by exposure to the input language, as determined by the average distance from the head of a predicate (verb) to its arguments (e.g., subject and object). Languages with larger average distances between verbs and their arguments will in general require that predicates be more highly activated to permit the necessary attachments over longer distances. This larger predicate activation results in a greater preference to attach to the predicate in an ambiguity and thus to a

larger influence of predicate proximity in such languages. Because Spanish word order is freer than that in English, word orders such as VOS (verb–object–subject) will be more common, and thus verbs and their arguments will be on average more widely separated in Spanish, leading to a stronger influence of predicate proximity in Spanish.

However, an alternative candidate for the factor that interacts with recency is Hemforth et al.'s (1997) *anaphoric binding hypothesis*, which specifies that the parser initiates a search for the appropriate referent for a pronoun when the pronoun is first encountered. This process influences RC attachment because a search is initiated for the relative pronoun heading an RC (e.g., *who*, *which*, *that*, *que*) just as for any other pronoun. Hemforth et al. assumed that the parser prefers to coindex pronouns to elements that are part of the main assertion of a sentence (cf. de Vincenzi & Job, 1995; Frazier, 1990; Frazier & Clifton, 1996; Gibson, Pearlmutter, et al., 1996), and thus structurally higher NPs are preferred as targets for coindexation. Because RC attachment must follow relative pronoun coindexation, higher RC attachments are preferred. Hemforth et al. proposed that the weighting of the anaphoric binding factor varies across languages depending on whether relative pronouns are always lexically realized within a language. Because English allows nonlexical relative pronouns (e.g., *the man* [*who*] *John saw*), the strength of the anaphoric binding factor is weaker in English than in languages like Spanish and German, which always require an overt relative pronoun in RCs. Thus the pressure to attach high is weaker in English, and recency dominates, even in examples with only two NPs.

In addition to the possible alternatives in a two-factor account of attachments in 2NP and 3NP constructions, Mitchell and Cuetos's (1991; Cuetos et al., 1996) tuning hypothesis is in principle able to account for the present results and others. According to this hypothesis, the parser tunes its preferences on a construction-by-construction basis within a language, as determined by the relative frequencies of the alternatives with which an ambiguity is resolved. However, as noted by Cuetos et al. (1996), the tuning hypothesis is essentially a broad class of proposals rather than a specific theory. At present, it remains unclear whether a model with the appropriate grain size for tracking statistical preferences can be found. For example, differences in preferences across languages and attachment constructions indicate that any of the following can in principle affect attachment preferences: (1) the category of the attaching phrase; (2) the categories, number, and order of the potential attachment sites; and (3) any context intervening between the prospective sites. Thus a tuning theory must track this information. However, Gibson, Schütze, and Salomon (1996; Gibson & Schütze, 1999), examining conjunction of an NP to one of three possible sites in a 3NP construction, demonstrated that the frequency of attachment to a particular site (counted from a corpus) did not correctly predict processing difficulty for comprehenders. Whether an appropriate grain size can be found that successfully predicts both RC attachment and the Gibson, Schütze, and Salomon conjunction results is unclear.

A final class of models to consider with respect to the present data are constraint-based lexicalist approaches (e.g., MacDonald et al., 1994; Trueswell & Tanenhaus, 1994). The present results clearly indicate that lexically based preferences and plausibility biases are not sufficient to account for the pattern of data in 2NP and 3NP constructions, and thus it appears that if constraint-based models are to handle these results, they must allow at least some structural-complexity (or perhaps structural-frequency; see, e.g., Tabor et al., 1997) metrics to apply in the constraint-satisfaction process. One approach to this might be to construe recency as a fundamental property of any process that sequentially constructs a representation in working memory, regardless of whether the representation involves syntax, semantics, discourse, or some nonlinguistic form. Portions of a representation that are made available early in processing will tend to decay over time if not otherwise protected (e.g., by predicate proximity, although this would presumably be a language-specific mechanism). Recency on such a story is thus interestingly different from, for example, Frazier's (1978, 1987a) minimal attachment principle, in that the latter depends on very specific properties of a syntactic representation (i.e., the number of new syntactic nodes required for attachment). Thus while much effort in the constraint-based lexicalist framework has been devoted to replacing structural-complexity metrics like minimal attachment with lexical biases (see, e.g., MacDonald et al., 1994; Spivey-Knowlton & Sedivy, 1995; Trueswell et al., 1994), it might not be surprising that a nonlexical metric like recency is necessary in such models.

REFERENCES

Boland, J. E., Tanenhaus, M. K., Garnsey, S. M., & Carlson, G. N. (1995). Verb argument structure in parsing and interpretation: Evidence from wh-questions. *Journal of Memory & Language*, **34**, 774-806.

Brysbaert, M., & Mitchell, D. C. (1996). Modifier attachment in sentence parsing: Evidence from Dutch. *Quarterly Journal of Experimental Psychology*, **49A**, 664-695.

Carreiras, M., & Clifton, C., Jr. (1993). Relative clause interpretation preferences in Spanish and English. *Language & Speech*, **36**, 353-372.

Carreiras, M., & Clifton, C., Jr. (1998). *Another word on parsing relative clauses: Eye-tracking evidence from Spanish and English*. Manuscript submitted for publication.

Clark, H. H. (1973). The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning & Verbal Behavior*, **12**, 335-359.

Clifton, C., Jr., Speer, S., & Abney, S. P. (1991). Parsing arguments: Phrase structure and argument structure as determinants of initial parsing decisions. *Journal of Memory & Language*, **30**, 251-271.

Cuetos, F., & Mitchell, D. C. (1988). Cross-linguistic differences in parsing: Restrictions on the use of the Late Closure strategy in Spanish. *Cognition*, **30**, 73-105.

Cuetos, F., Mitchell, D. C., & Corley, M. M. B. (1996). Parsing in different languages. In M. Carreiras, J. E. García-Albea, & N. Sebastián-Gallés (Eds.), *Language processing in Spanish* (pp. 145-187). Mahwah, NJ: Erlbaum.

de Vincenzi, M., & Job, R. (1995). An investigation of late closure: The role of syntax, thematic structure, and pragmatics in initial and

final interpretation. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **21**, 1303-1321.

Ferreira, F., & Clifton, C., Jr. (1986). The independence of syntactic processing. *Journal of Memory & Language*, **25**, 348-368.

Frazier, L. (1978). *On comprehending sentences: Syntactic parsing strategies*. Unpublished doctoral dissertation, University of Connecticut, Storrs.

Frazier, L. (1987a). Sentence processing: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 559-586). Hillsdale, NJ: Erlbaum.

Frazier, L. (1987b). Syntactic processing: Evidence from Dutch. *Natural Language & Linguistic Theory*, **5**, 519-559.

Frazier, L. (1990). Parsing modifiers: Special purpose routines in the human sentence processing mechanism? In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 303-330). Hillsdale, NJ: Erlbaum.

Frazier, L. (1995). Constraint satisfaction as a theory of sentence processing. *Journal of Psycholinguistic Research*, **24**, 437-468.

Frazier, L., & Clifton, C., Jr. (1996). *Construal*. Cambridge, MA: MIT Press.

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology*, **14**, 178-210.

Gibson, E. (1991). *A computational theory of human linguistic processing: Memory limitations and processing breakdown*. Unpublished doctoral dissertation, Carnegie Mellon University, Pittsburgh.

Gibson, E. (1998). Syntactic complexity: Locality of syntactic dependencies. *Cognition*, **68**, 1-76.

Gibson, E., & Pearlmutter, N. J. (1994). A corpus-based analysis of psycholinguistic constraints on prepositional-phrase attachment. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 181-198). Hillsdale, NJ: Erlbaum.

Gibson, E., Pearlmutter, N. J., Canseco-Gonzalez, E., & Hickok, G. (1996). Recency preference in the human sentence processing mechanism. *Cognition*, **59**, 23-59.

Gibson, E., & Schütze, C. T. (1999). Disambiguation preferences in noun phrase conjunction do not mirror corpus frequency. *Journal of Memory & Language*, **40**, 263-279.

Gibson, E., Schütze, C. T., & Salomon, A. (1996). The relationship between the frequency and the processing complexity of linguistic structure. *Journal of Psycholinguistic Research*, **25**, 59-92.

Gilboy, E., & Sopena, J. M. (1996). Segmentation effects in the processing of complex NPs with relative clauses. In M. Carreiras, J. E. García-Albea, & N. Sebastián-Gallés (Eds.), *Language processing in Spanish* (pp. 191-206). Mahwah, NJ: Erlbaum.

Gilboy, E., Sopena, J. M., Clifton, C., Jr., & Frazier, L. (1995). Argument structure and association preferences in Spanish and English complex NPs. *Cognition*, **54**, 131-167.

Heim, I. (1982). *The semantics of definite and indefinite noun phrases*. Unpublished doctoral dissertation, University of Massachusetts, Amherst.

Hemforth, B., Konieczny, L., & Scheepers, C. (1997). *Syntactic attachment and anaphor resolution: The two sides of relative clause attachment*. Unpublished manuscript, University of Freiburg, Freiburg, Germany.

Hindle, D., & Rooth, M. (1993). Structural ambiguity and lexical relations. *Computational Linguistics*, **19**, 103-120.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General*, **111**, 228-238.

Kamp, H. (1981). A theory of truth and semantic representation. In J. A. G. Groenendijk, T. M. V. Janssen, & M. B. J. Stokhof (Eds.), *Formal methods in the study of language* (pp. 255-278). Amsterdam: Mathematical Centre Tracts.

Kimball, J. (1973). Seven principles of surface structure parsing in natural language. *Cognition*, **2**, 15-47.

Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review*, **1**, 476-490.

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, **101**, 676-703.

MacDonald, M. C., & Thornton, R. B. (1996, March). *Constraint-based models and modification ambiguities*. Poster presented at the Ninth Annual CUNY Conference on Human Sentence Processing, New York.

Mitchell, D. C., & Cuetos, F. (1991). The origins of parsing strategies. *Conference Proceedings: Current Issues in Natural Language Processing* (pp. 1-12). University of Texas, Austin.

Mitchell, D. C., Cuetos, F., & Zagar, D. (1990). Reading in different languages: Is there a universal mechanism for parsing sentences? In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 285-302). Hillsdale, NJ: Erlbaum.

Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing: Eye movements in the analysis of semantically biased sentences. *Journal of Verbal Learning & Verbal Behavior*, **22**, 358-374.

Schriefers, H., Friederici, A. D., & Kuhn, K. (1995). The processing of locally ambiguous relative clauses in German. *Journal of Memory & Language*, **34**, 499-520.

Schütze, C. T., & Gibson, E. (in press). Argumenthood and the PP attachment ambiguity in English. *Journal of Memory & Language.*

Spivey-Knowlton, M., & Sedivy, J. (1995). Resolving attachment ambiguities with multiple constraints. *Cognition*, **55**, 227-267.

Tabor, W., Juliano, C., & Tanenhaus, M. K. (1997). Parsing in a dynamical system: An attractor-based account of the interaction of lexical and structural constraints in sentence processing. *Language & Cognitive Processes*, **12**, 211-271.

Taraban, R., & McClelland, J. L. (1988). Constituent attachment and thematic role assignment in sentence processing: Influences of content-based expectations. *Journal of Memory & Language*, **27**, 597-632.

Trueswell, J. C., & Tanenhaus, M. K. (1994). Towards a lexicalist framework of constraint-based syntactic ambiguity resolution. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 155-179). Hillsdale, NJ: Erlbaum.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. *Journal of Memory & Language*, **33**, 285-318.

Winer, B. J. (1971). *Statistical principles in experimental design* (2nd ed.). New York: McGraw-Hill.

NOTES

1. Note that the present experiment cannot rule out a potentially even more subtle effect of plausibility, arising from the possibility that inserting a third (high) site would alter the plausibility of attaching to the other two sites. For example, in *the counter in the kitchen that was spotless*, modification of *counter* by *that was spotless* is quite plausible, but it is much less so in *the grime on the counter in the kitchen that was spotless*. Although we cannot definitively rule out this type of plausibility explanation, it seems unlikely given our stimuli (see the Appendix).

2. All paired comparisons used the MS_e term from the corresponding one-way ANOVA (by participants or by items, Winer, 1971).

3. Note that lexical biases must play a role in at least our 3NP items, in order to explain why the second PP preferentially attaches to the immediately preceding NP in the norming survey, contrary to predicate proximity's preference to attach to the earlier NP site.

APPENDIX

The low-attachment versions of the experimental stimuli are listed below with their English translations. The other versions were always created by changing the number marking on the attachment sites so that a different site matched the number of the relative clause verb. The material in parentheses for each item was included only in its 3NP versions, and material in square brackets was included only in an item's 2NP versions. See the Materials section of the experiment for further details. The text in boldface is the disambiguating region. The number in parentheses following each item's translation is the percentage of participants in the norming survey (see Method section) who reported that the second PP in the 3NP versions attached to the

middle NP site (as desired) rather than to the high site. The item marked with an asterisk contained an error in its 3NP middle-attachment version and was excluded from analyses, as described in the Results section.

1. Un alumno insultó a (la secretaria de)l profesor de las clases que no **gustaron a los** estudiantes. A student insulted (the secretary of) the professor of the courses that were disliked by the students. (100)

2. El coche recogió (el paquete del) [al] auxiliar de los ingenieros que **llegaron en el** avión. The car picked up (the package of) the helper of the engineers who arrived by airplane. (100)

3. El banco reclamó (el contrato d)el préstamo de los pisos que se **concedieron el año** pasado. The bank reclaimed (the contract of) the loan of the apartments that were conceded last year. (87)

4. El barco disparó contra (el depósito d)el motor de los bombarderos que se **destruyeron en la** batalla. The ship shot at (the tank of) the motor of the bombers that were destroyed in the battle. (80)

5. Daniel reparó (la tubería de) la pared de los baños que se **construyeron de forma** precipitada. Daniel repaired (the pipe of) the wall of the bathrooms that were built hastily. (80)

6. La policía descubrió (la huella del) [al] culpable de los asesinatos que se **investigaron en el** juicio. The police discovered (the fingerprint of) the culprit in the murders that were investigated in the trial. (100)

7. El cocinero preparó (la salsa de) la receta de las revistas que **resultaron ser un** total fracaso. The cook prepared (the sauce of) the recipe of the magazines that turned out to be a total failure. (93)

8. El compositor revisó (la pieza d)el concierto de los solistas que se **presentarán al público** la próxima temporada. The composer revised (the piece of) the concert of the soloists who will be presented to the public next season. (87)

9. El estudiante leyó (la crítica d)el libro de los novelistas que **aburrieron a los** lectores. The student read (the criticism of) the book by the writers who bored the readers. (87)

10. El jardinero seleccionó (la semilla de) la planta de los cultivos que se **mostraron en la** feria. The gardener selected (the seed of) the plant of the crops that were shown at the fair. (87)

11. El comentarista presentó (el premio del) [al] ganador de las pruebas que se **seleccionaron para el** concurso. The commentator presented (the prize of) the winner of the tests that were selected for the competition. (93)

12. La actriz interpretó (el personaje d)el guión de los escritores que **fueron criticados por** la prensa. The actress interpreted (the character of) the script of the writers who were criticized by the press. (100)

13. El arqueólogo describió (la extracción d)el fósil de los dinosauros que se **estudiaron en el** informe. The archeologist described (the extraction of) the fossil of the dinosaurs that were studied in the report. (100)

14. El juez escuchó (la declaración del) [al] testigo de los crímenes que **salieron en los** medios de comunicación. The judge listened to (the statement of) the witness of the crimes that appeared in the media. (100)

15. El veterinario inspeccionó (el tejido d)el pulmón de los animales que se **diseccionaron en el** experimento. The veterinarian examined (the tissue of) the lung of the animals that were dissected in the experiment. (87)

16. El espectador vió (los debates de) las películas del director que **apareció en la** televisión. The spectator watched (the debates of) the movies of the director who appeared on the TV. (93)

17. El verdugo ejecutó a (los consejeros de) los embajadores del rey que **fue desterrado de** su país. The executioner executed (the advisors of) the ambassadors of the king who was exiled from his country. (100)

18. El público aplaudió (las interpretaciones de) los conciertos del músico que se **escuchó en la** ópera. The public applauded (the interpretations of) the concerts of the music that was heard in the opera. (80)

19. Carlos trabajaba con (los asesores de) los abogados de la empresa que **colaboró en el** caso. Carlos worked with (the advisors of) the lawyers of the enterprise that cooperated in the case. (100)

20. El astrónomo predijo (los cambios de) las órbitas del planeta que se **observó desde el** satélite. The astronomer predicted (the changes of) the orbits of the planet that was observed from the satellite. (93)

21. El tren transportó (las reproducciones de) las pinturas del artista que se **presentó en la** exposición. The train carried (the reproductions of) the paintings of the artist who was presented at the exhibition. (100)

22. Susana criticó (las fotografías de) [a] las actrices de la película que **fue un escándalo** en todo el país. Susana criticized (the photographs of) the actresses of the movie that was a scandal all over the country. (93)

23. El científico consiguió (las patentes de) las lentes del telescopio que se **adquirió en el** congreso. The scientist got (the patents of) the lenses of the telescope that was bought in the convention. (100)

24. El electricista instaló (los cables de) los circuitos de la antena que se **estropeó en la** inauguración de la emisora de radio. The electrician installed (the cables of) the circuits of the antenna that was ruined in the opening of the radio station. (87)

25. La modista diseñó (los estampados de) las telas de la chaqueta que **fue elaborada en** la fábrica. The dressmaker designed (the prints of) the fabrics of the jacket that was manufactured in the factory. (100)

26. El editor leyó (las revisiones de) los artículos del periodista que **fue criticado por** el gobierno. The publisher read (the revisions of) the articles of the journalist who was criticized by the government. (93)

27. *El cazador capturó (las crías de) los rinocerontes del cuidador que **estaba cerca del** campamento. The hunter caught (the children of) the rhinoceroses of the caretaker who was near the camp. (93)

28. El comité organizó (las entregas de) los premios del científico que **fue objeto de** un reportaje. The commitee organized (the deliveries of) the prizes of the scientist who was the topic of a report. (93)

29. Dolores llamó a (los amigos de) los invitados del anfitrión que **bebió demasiado alcohol** en la fiesta. Dolores called (the friends of) the guests of the host who drank too much alcohol at the party. (87)

30. El campesino se encontró con (los perros de) los pastores del rebaño que se **perdió en el** bosque. The farmer encountered (the dogs of) the shepherds of the flock that got lost in the forest. (100)