Chapter 3

Relative clause attachment in Japanese

In the sentence processing literature, principles such as right association, late closure, and locality have often been assumed to apply universally across languages, favouring the interpretation in which a modifying phrase is attached to the closest possible site (Frazier & Fodor, 1978; Gibson, 1991, 1998; Kimball, 1973; Phillips, 1995). Recent proposals by Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok (1996) and Hemforth, Konieczny & Scheepers (in press) have refined this view by suggesting factors that modulate locality, so as to account for cross-linguistic results in the attachment of relative clauses (RCs) (see Cuetos, Mitchell & Corley, 1996, for a recent overview). The purpose of the present paper is to investigate the attachment preferences of head-final RCs in Japanese.

Reading time evidence presented by Gibson et al. (1996) showed that, in sentence fragments such as Examples (38a) and (38b) with three potential host nouns, native speakers preferred to attach the RC to the low noun (i.e., N₃, the lowest candidate noun in the tree structure) both in Spanish and in English. Furthermore, attachment to the high noun (N₁) was preferred over the middle noun (N₂). Similar results were obtained with complete sentences in Spanish (Gibson, Pearlmutter & Torrens, in press) and German (Walter & Hemforth, 1998), but a high over low attachment seems to be preferred in Dutch (Wijnen, 1998).

1 This work was conducted in collaboration with E. Gibson, N. Pearlmutter, T. Aikawa and S. Miyagawa.
(38) head-initial RCs

\[ \text{N}_1 \] la(s) lámpara(s) cerca de la(s) \text{p}intura(s) \text{ de la(s)} \text{casa(s)} [ \text{que fue dañada en la inundación}] \\
\text{b. the lamp(s) near the painting(s) of the house(s) [that was damaged in the flood]}

The overall preference for low attachment found by Gibson et al. (1996) is compatible with locality. However, the advantage of the high over the middle noun is not. In order to explain this U-shaped preference curve (i.e., with the middle noun as the least preferred site), Gibson et al. (1996) proposed a second factor which prefers the attachment of the modifying phrase to the high site (\( \text{N}_1 \)) and therefore competes with locality. The attachment preference then results from the interaction of these two factors. More specifically, these authors proposed the predicate proximity principle, according to which modifiers are preferentially attached to the phrase closest in structural terms to the predicate of the sentence. In the construction in Example (38), predicate proximity is not strong enough to override locality, hence the preference for \( \text{N}_3 \). But it is strong enough to yield the preference for \( \text{N}_1 \) over \( \text{N}_2 \).

Hemforth, Koniczny & Schepers (in press; 1997) suggested an alternative proposal in which the factor favouring the attachment of a RC to the higher site is related to the process of finding the antecedent for the relative pronoun in the RC (e.g., who in English). This process is biased towards discourse salient entities such as the head of a complex NP (e.g., \( \text{N}_1 \) in Example (38)).

The purpose of this paper is to explore some aspects of RC attachment when three potential host nouns are available. In particular, we will consider the case in which the RC precedes the head nouns and is not initiated by a complementizer or a relative pronoun, as in Example (39).

(39) head-final RCs

\[ \text{RC \ N}_3 \text{ postposition \ N}_2 \text{ postposition \ N}_1 \]

In Example (39), we have the head-final RC construction in languages such as Japanese, Korean and Tamil, which have postpositions rather than prepositions and therefore present the nouns in the opposite order to that of head-initial languages (cf. Example (38)). In structural terms, the noun closest to the RC (\( \text{N}_3 \)) is still the lowest, and the farthest one (\( \text{N}_1 \)) is the highest noun available for attachment inside the complex NP.

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Assuming an incremental parser, which processes each incoming word immediately and tries to integrate it without delay to the phrase marker built so far (e.g., Marslen-Wilson & Tyler, 1980, 1981), the positioning of the head nouns after the RC in the head-final RC construction makes it particularly interesting to compare to its head-initial counterpart. In head-initial RC constructions, the attachment decision is made after the three nouns have been encountered. In head-final RCs, however, the RC is processed first and only then are the nouns detected. Hence, under an incremental model, the parser should attempt to attach the RC to each incoming noun in turn until a successful attachment is made. Because the first noun (N₃) is the only available candidate initially, it is natural to expect it to be the most preferred site for attachment. If attachment to the first noun is not successful, incrementality predicts that the middle noun is favoured over the high noun as the parser attempts to resolve the attachment as soon as possible.

However, this overlooks an important factor in the processing of head-final constructions. In such constructions, the parser’s decisions may be influenced by a category that is predicted to be upcoming in the input string. Evidence that predicted categories influence the parser’s behaviour is provided by Yamashita (1994) who showed that native Japanese speakers do not wait for the detection of a verb in order to start interpreting a sequence of NPs. Instead these NPs are interpreted as the arguments of a predicted verb whose features are only partially determined by the case markers on those NPs.

Thus, when discussing the processing of head-final RC constructions with multiple potential heads, it is necessary to consider whether there is partial information predicting a category, and, if so, how such information could affect the attachment of the RC. First, partial information may be available in this construction in the form of a particle (e.g., a postposition) marking a noun being processed, which indicates that a higher noun is to come. For example, when processing N₃ in Example (39) above, the parser may be already predicting another noun because of the postposition that immediately follows N₃. Assuming that such a particle does predict a higher noun, there are two alternative ways for the parser to treat such partial information with respect to attachment decisions. It is conceivable that the parser only takes into account candidate sites whose heads have already been lexically realized. We will refer to this alternative as parsing with lexically-realized candidates only, or
\textit{LexCat}-parsing. Alternatively, the parser may also consider attaching the RC to a predicted site whose head is still to be processed, even if a lexically-realized candidate is already available. We will refer to this alternative as parsing with predicted categories as candidates, or \textit{PredCat}-parsing. Consider the predictions that LexCat- and PredCat-parsing make in the head-final RC construction with three candidate sites. In LexCat-parsing, only lexically-realized sites are considered, hence the parser favours attachment to the nouns in the order they become available — low, middle, high — a monotonic decreasing preference ordering of the sites. In PredCat-parsing, however, both predicted as well as lexically-realized sites are considered as candidates for attachment. Therefore it is possible that an upcoming site may be preferred over a site already available depending on the interplay between locality and the factor(s) favouring the higher site. In particular, an alternative to the monotonic prediction is suggested by the U-shaped curve obtained by Gibson et al. (1996) in the head-initial RC construction. Such a U-shaped result, or any result where a higher site is preferred over a lower one, would be compatible with PredCat-parsing, but not with LexCat-parsing.

Kamide and colleagues provide some suggestive evidence for PredCat-parsing in two self-paced reading experiments testing the attachment of head-final RCs with two potential hosts in Japanese. In the first experiment, Kamide & Mitchell (1997) reported an initial advantage for low attachment, supporting locality. In a follow-up experiment (Kamide, Mitchell, Fodor & Inoue, 1998), the segmentation for their self-paced presentation was modified so that, contrary to the presentation in the original experiment, the first head noun and the following particle (the genitive marker \textit{no}) were presented in the same region. Although the low condition was still faster than the high condition, this difference was no longer significant. This suggests that locality was weakened by the visibility of the genitive marker, which signalled that another site was upcoming. However, this is a null result, and more convincing evidence in support of PredCat-parsing would be results showing a preference to attach a head-final RC to a higher candidate over a lower one.

The PredCat/LexCat distinction interacts with proposals made in the literature to account for the attachment of modifiers. In the proposal by Hemforth, Konieczny & Scheepers (in press; 1997), two independent processes compete and the first to come up with a candidate site is the winner. In this model, which we will refer to as the \textit{race model}, one
process involves syntactic factors which favour the closest site (locality), whereas the second process is anaphor resolution, that is, finding the antecedent for the relative pronoun of a RC. The anaphor resolution process in itself can favour either type of site, predicted or lexically-realized, as it does not necessarily require a lexical item or a fully specified entity. The race component of the model, however, implies that the winner is the entity that displays the higher activation level at the earliest possible point. Because predicted sites do not have a corresponding activated entity in the discourse, the race component of this model requires that only lexically-available sites be considered as potential sites, in accordance with LexCat-parsing. In this fashion, it is immaterial that the anaphor process prefers the high noun for discourse salience reasons, as this noun only becomes available later in the sentence. Thus, the race model predicts a monotonic preference ordering among the sites (namely, N₃, N₂, N₁) and would be contradicted by a U-shaped result. Note that here, we can dissociate two components of the race model. On the one hand, there is the race component itself, arguing for the earliest, most activated entity in the discourse. On the other hand, there is the anaphor resolution process, favouring the higher sites for discourse reasons, which could be interpreted within a model distinct of a race metaphor.

The same monotonic prediction is made by parameterized head attachment (Konieczny, Hemforth, Scheepers & Strube, 1997) which explicitly assumes LexCat-parsing. According to this proposal, arguments and modifiers should be preferentially associated with a lexically-realized head, disfavouring predicted categories and implying in the present construction that the nouns are preferred in the order that they become available.

Predicate proximity (Gibson et al., 1996), on the other hand, is not bound to PredCat- or LexCat-parsing. In this proposal, the factor favouring higher sites is related to their closer structural proximity to the main predicate of the clause, which in itself requires neither that the potential candidates must all be lexically-realized nor that predicted categories should be taken into consideration. Considering that the discourse salience in Hemforth and colleagues’ anaphor resolution process may have its origin in a predicate proximity-like factor (Hemforth, Konieczny & Scheepers, 1997, fn. 8), it should not be surprising that both principles present a similar neutrality in relation to partial information use, which allows them to be interpreted within a LexCat- or a PredCat-parsing framework. Within a LexCat-
parsing framework, the preferences of either predicate proximity or anaphor resolution for the high site would be irrelevant because this site would only be lexically available later than lower sites, and as a result the prediction for a monotonic ordering of the potential sites should still follow. In PredCat-parsing, the predictions would depend on the weights that one assigns to the strength of the factors favouring the low site (locality) and the high site (predicate proximity or anaphor resolution) at each point during the processing of the RC heads. With the exception of the middle site being preferred overall, such assignment of weights within PredCat-parsing could account for most outcomes in the present experiment, but if the weights of the factors at play in the head-final RC construction should mirror the ones proposed for head-initial RCs (Gibson et al., 1996), then a U-shaped preference ordering of the sites would be the expected result.

More generally, there are clearly two distinct predictions being made in relation to attachment preferences in head-final RC constructions with three head nouns. First, there is the prediction for a monotonic curve with the middle (N₂) being preferred over the high (N₁). And second, there is the prediction for a U-shaped curve, in which the middle site (N₂) is the least preferred. In both cases, the most local site (N₃) is predicted to be the most preferred. We investigated these predictions in the head-final RC construction with three potential attachment sites in Japanese.

3.1 Method

3.1.1 Participants

Thirty-nine native speakers of Japanese participated for $20 each. They had all come to the U.S. as adults and were residents of the Boston area. One participant was eliminated for answering the comprehension questions at chance level, and two were eliminated because of extremely long or short baseline reading times (see the Analysis section for details).
3.1.2 Materials

Sentences like those in Example (40) were presented using Japanese characters, with the attachment of the RC disambiguated by plausibility. In Example (40a), the RC is biased towards the low site (N3); in Example (40b), towards the middle site (N2); and in Example (40c), towards the high site (N1). Appendix 3-B contains a complete list of the stimuli. The potential attachment sites are underlined in Example (40); the slashes indicate the divisions between regions for the self-paced reading presentation.

(40) head-final RCs

a. \[\text{Eda-ga} \ \text{oreteiru}\] / branch-Nom / N3 \[\text{shigemi-no yoko-no} \ \text{hitto-no ushiro-no}\] / bush / person / N2 \[\text{jitensha-wa} \ \text{kireide} \ \text{ooki-katta}\] / N1-topic \[\text{pred}_1 / \text{pred}_2\]

b. \[\text{Paati-de atta} / \ldots\] / party-Loc / met

c. \[\text{Gakkou-made notta} / \ldots\] / school-to / rode

‘The bicycle behind the person beside the bush that has a broken branch was pretty and big.’

\[\text{I met at the party}\]
\[\text{I rode to school}\]

In order to control for potential lexical and plausibility differences, the three head nouns were rotated through the three attachment sites for each of the three plausibility-biased RCs, yielding a total of nine sub-conditions, as schematically represented in Table 3.1.2.

Because of the plausibility biases, each RC in Table 3.1.2 has to attach to the same noun (as the subscripts A, B, C indicate), but the position of the noun itself varies from condition to condition. For example, the RC met at the party should always attach to person, but the position of this head noun (high, middle or low) will depend on the subcondition that the participant sees.

In the segmentation of the sentences for the self-paced reading presentation, regions 2 and 3 include a head noun and a postposition together. Words are not usually separated by spaces in written Japanese, hence there is no a priori natural way to segment the regions. However, two factors led us to display each PP (i.e., a postpositional phrase comprised of a postposition with its preceding noun) as a single region. First, particles such as no (which
<table>
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<tr>
<th>Condition (a)</th>
<th>RC&lt;sub&gt;A&lt;/sub&gt;</th>
<th>N&lt;sub&gt;A&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</th>
<th>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</th>
<th>N&lt;sub&gt;C&lt;/sub&gt; Topic</th>
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<td>Mid (b)</td>
<td>RC&lt;sub&gt;B&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; Topic</td>
<td>pred&lt;sub&gt;1&lt;/sub&gt;</td>
<td>pred&lt;sub&gt;2&lt;/sub&gt;</td>
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<tr>
<td>High (c)</td>
<td>RC&lt;sub&gt;C&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; Topic</td>
<td>pred&lt;sub&gt;1&lt;/sub&gt;</td>
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<td>N&lt;sub&gt;C&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; Topic</td>
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<td>pred&lt;sub&gt;2&lt;/sub&gt;</td>
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<tr>
<td>High (e)</td>
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<td>N&lt;sub&gt;A&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; Topic</td>
<td>pred&lt;sub&gt;1&lt;/sub&gt;</td>
<td>pred&lt;sub&gt;2&lt;/sub&gt;</td>
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<td>Low (f)</td>
<td>RC&lt;sub&gt;C&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
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<td>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; Topic</td>
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<tr>
<td>Low (h)</td>
<td>RC&lt;sub&gt;B&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; Topic</td>
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<td>Mid (i)</td>
<td>RC&lt;sub&gt;C&lt;/sub&gt;</td>
<td>N&lt;sub&gt;B&lt;/sub&gt; postp&lt;sub&gt;1&lt;/sub&gt;</td>
<td>N&lt;sub&gt;C&lt;/sub&gt; postp&lt;sub&gt;2&lt;/sub&gt;</td>
<td>N&lt;sub&gt;A&lt;/sub&gt; Topic</td>
<td>pred&lt;sub&gt;1&lt;/sub&gt;</td>
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Note: letter subscripts indicate attachment, so that RC<sub>A</sub> plausibly attaches only to N<sub>A</sub>, for example. Postp = postposition; topic = topic marker; pred = predicate.

Table 3.1: Regions for self-paced reading presentation.

initiated the locatives used as postpositions) mark the previous noun and are not used on their own. Second, the comparison between LexCat-parsing and PredCat-parsing is only possible if the partial information (i.e., the postposition predicting a higher noun) is available at the earliest possible point. For LexCat-parsing any such delay would not have any impact (as the parser is not taking partial information into account), but for PredCat-parsing a slight delay may disrupt the use of the information and could create a confound.

Nine lists were created by distributing the thirty-six stimuli in a Latin Square design. Each participant saw exactly one of the lists intermixed with 65 unrelated items in pseudo-random order. After each sentence, participants answered a yes/no comprehension question presented on a new screen.

3.1.3 Stimulus norming

A crucial assumption in this kind of experiment is that attachment to each of the three sites is equally grammatical. In particular, in the present case, it is necessary to guarantee that attachment of the RC to N<sub>2</sub> is grammatical by making sure that the first PP (N<sub>3</sub> postp<sub>1</sub>) modifies N<sub>2</sub> (see Figure 3.1) and not N<sub>1</sub> (see Figure 3.2). In the latter structure, it would not be possible to attach the RC to N<sub>2</sub>, assuming that attachments leading to crossing branches

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in the tree structure are ungrammatical.

Figure 3.1: $N_3$ modifying $N_2$ — RC can attach to any of the 3 nouns.

Figure 3.2: $N_3$ modifying $N_1$ — RC cannot attach to $N_2$.

To ensure that the PP containing $N_3$ is modifying $N_2$ and not $N_1$ in our stimuli, we presented a separate group of 46 native Japanese speakers with fragments like Example (41a) and questions about which of $N_1$ or $N_2$ was modified by $N_3$, as in Example (41b).
(41)

\[ N_A \text{ post}_1 N_B \text{ post}_2 N_C \]

a. shigemi-no yoko-no hito-no ushiro-no jitensha
   bush beside person behind bicycle
   “the bicycle behind the person beside the bush”

b. shigemi-no yoko-ni-wa hito-ga imasuka soretomo jitensha-ga arimasuka?
   bush beside-Loc -top person-Nom is or bicycle-Nom is?
   “Is the person or the bicycle beside the bush?”

As in Table 3.1.2, each triple of head nouns was rotated through three different orderings, yielding a total of 108 ordered triples of nouns. Each participant saw exactly one of the orderings of each of the 36 triples mixed pseudo-randomly with 44 filler items. Some of the fillers were biased for low or high attachment and were used to ensure that participants were not using any particular strategy in the survey. Nine participants’ data were eliminated for not answering these foil items appropriately.

As expected, participants had a strong preference for the low attachment, choosing to attach \( N_3 \) to the lower noun (\( N_2 \)) more than 85% of the time. In each of the 36 triples, low attachment was preferred at least 75% of the time.

### 3.1.4 Procedure

The experiment was conducted on a Power Macintosh 7500/100 running PsyScope (Cohen, MacWhinney, Flatt & Provost, 1993). Participants were timed in a phrase-by-phrase self-paced non-cumulative moving-window reading task (Just, Carpenter & Woolley, 1982) controlled by a button-box. Stimuli initially appeared as dots, and participants pressed the leftmost button of the button-box to reveal each subsequent region of the sentence and cause all other regions to revert to dots. At the end of each sentence, a yes/no question appeared on a new screen, which participants answered by pressing one of two buttons. No feedback was given.

The experimental trials were preceded by one screen of instructions and eight practice trials. All sentences were presented on a single line. The experiment took participants approximately 20 minutes.
3.1.5 Analysis

We analyzed comprehension question response accuracy and reading times. For the purposes of analysis and presentation of the data, the nine sub-conditions in Table 3.1.2 were collapsed into the three conditions of interest (low, mid, high attachment).

Analyses were conducted on residual reading times per region (Ferreira & Clifton, 1986), derived by subtracting from raw reading times each participant’s predicted time to read regions of the same length (measured in number of characters), which in turn was calculated from a linear regression equation across all of a participant’s sentences in the experiment. The residual reading times were trimmed so that data points beyond four standard deviations from the relevant condition × region cell mean were discarded, corresponding to less than 1% of the total data. The means and analyses presented below are based on the trimmed residual reading times. The same patterns were present in the raw reading times. See Appendix 3-A for a graph of the raw reading times in each condition.

Two participants were eliminated for having unusual intercepts in their regression equations (1949 ms and -1505 ms). The other 36 participants had intercepts between 155 and 1008 ms (M = 524 ms; SD = 232 ms). Inclusion of the two participants eliminated did not alter the patterns in the data.

3.2 Results

3.2.1 Comprehension question response accuracy

Performance in the low attachment condition (91.2% correct) was better than in the middle (85.2%) (F₁(1,35) = 8.51, p < 0.01; F₂(1,35) = 12.3, p < 0.01) or the high (85.6%) conditions (F₁(1,35) = 9.33, p < 0.01; F₂ (1,35) = 8.23, p < 0.01), but the high and middle conditions did not differ (Fs < 1).
3.2.2 Reading times

Figure 3.3 shows the residual reading times by region. No differences were detected (Fs < 1) in the first region (the RC). In region 2 (the first PP), the low attachment condition was significantly faster than the middle condition (F₁(1,35) = 5.37, p < 0.05; F₂(1,35) = 5.67, p < 0.05) and the high condition (F₁(1,35) = 10.5, p < 0.01; F₂(1,35) = 7.87, p < 0.01). The high and middle conditions did not differ (Fs < 1).

In region 3 (the second PP), the high condition was faster than the low condition (F₁(1,35) = 13.2, p < 0.01; F₂(1,35) = 11.9, p < 0.01) and the middle condition (F₁(1,35) = 8.76, p < 0.01; F₂(1,35) = 10.2, p < 0.01); but the low and middle conditions did not differ (F₁(1,35) = 1.17, p = 0.287; F₂(1,35) = 1.21, p = 0.278).

Region 4 (the third noun and the topic marker) presented the same pattern as region 3: the high condition was faster than the low condition (F₁(1,35) = 9.76, p < 0.01; F₂(1,35) = 10.4, p < 0.01) and the middle condition (F₁(1,35) = 15.4, p < 0.01; F₂(1,35) = 19.2, p < 0.01); and the low and middle conditions did not differ (Fs < 1).

In region 5 (the initial segment of the main predicate), the high condition was still faster than the low condition (F₁(1,35) = 4.18, p < 0.05; F₂(1,35) = 4.34, p < 0.05); but the middle condition did not differ from either the high condition (F₁(1,35) < 1; F₂(1,35) = 1.06) or the low condition (F₁(1,35) = 1.55, p = 0.222; F₂(1,35) < 1).

There were no differences in region 6 (the second part of the main predicate; Fs < 1).

Because the results of the norming study did not yield a 100% preference to attach the first PP low, it is possible that difficulty attaching the RC to the middle site could arise from the ungrammatical instances in which the first PP attached high. To ensure that our results were not due to these instances, analyses were also conducted upon the 12 items that, according to the off-line norming study, were most biased toward locally attaching the first PP. In those 12 items, the first PP attached low as desired an average of 92% of the time, with a minimum of 89% for any individual item. The numerical pattern of results for these items was identical to the pattern for the full set of stimuli. However, probably because of the small number of items in these analyses, the differences among the conditions in each region did not reach significance, except in region 4 (containing the high noun) where the
Figure 3.3: Residual reading times for each region.

high attachment condition was significantly faster than the middle condition ($F_1(1,35) = 8.83, p < 0.01$; $F_2(1,11) = 7.81, p < 0.05$) and the low condition ($F_1(1,35) = 4.41, p < 0.05$; $F_2(1,11) = 6.38, p < 0.05$), but the middle and low conditions did not differ ($Fs < 1$).

3.3 Discussion

The results of the experiment indicate a preference to attach according to locality. First, the percentage of correct responses to the comprehension questions supports the preference to attach the RC to the closest noun. Second, a preference for the closest site was detected in region 2 of the self-paced reading presentation (i.e., the first PP). Because region 2 included a head noun and a postposition together, participants were probably aware that another head noun was to follow. Thus, the slow reading times in this region in the middle and high conditions were due to a preference to attach to the most local noun. This pattern of results
is therefore similar to the initial low attachment preference observed by Kamide et al. (1997, 1998) in a construction with two potential attachment sites. (We analysed our data using raw reading times per character, which is the method used by Kamide and colleagues, and found the same overall pattern of results as in the analysis with residual reading times.)

The results also support a U-shaped over a monotonic preference ordering of the candidate sites, which argues against LexCat-parsing models in general, and parameterized head attachment (Konieczny et al., 1997) and the race model (Hemforth et al., in press, 1997) in particular. These models make the wrong prediction for not allowing predicted but not yet processed sites to be considered as candidates for modification. The evidence for the U-shaped preference curve comes from regions 3 and 4, where the reading time of the high condition was faster than in the middle condition. In region 3, in particular, the noun being read (N2) is compatible with the RC in the middle condition but not in the high condition. Therefore, the fact that this region was read slower in the middle than in the high condition suggests that attaching the RC to the middle site (in the middle condition) is harder than failing to attach the RC to this site (in the high condition), which strongly indicates that the middle site is dispreferred.

The reading times of the high condition in regions 2 (containing the low noun) and 3 (containing the middle noun) are particularly informative because in both cases the RC in this condition is incompatible with the head noun being read, but it is only in region 2 that the high condition is slower than the low. This suggests that the relatively slow reading time in region 2 in the high condition is not caused by the incompatibility between the head noun and the RC alone, otherwise a similar slow reading time should have occurred in region 3 as well. It is conceivable then that participants are attempting to attach the RC to each of the three incoming heads, and that they are only slow when the attachment fails with a favoured site (N3) and it is unproblematic when it fails at a less preferred site (N2), as long as they are aware that another potential site is to come.

The U-shaped preference curve supports the view that locality is overridden and a higher site is preferred for attachment even though the head of this site is only going to be available later than the lower site. This supports a PredCat-parsing model, in which the preference to attach to the high site over the middle site is explained by an independent factor. The
anaphor resolution process could be such a factor as it is not bound to either LexCat- or PredCat-parsing. Another possibility for the factor preferring the high site is predicate proximity, as it favours the sites structurally closer to a predicate and remains neutral to the use of partial information during parsing.

Overall, we can account for the U-shaped result in our experiment by adapting the proposal in Gibson et al. (1996) for head-initial RCs with three potential heads, as follows. When processing the low site, the parser considers attaching the RC to the current noun (N_3 in Example (39), repeated below as Example (42)) as well as to the noun predicted by the first postposition. However, because of locality strength at this point, the closest site (N_3) is preferred. If the low attachment fails for some reason (because of plausibility in the present experiment), the parser processes the middle site and considers the present noun (N_2) and the newly predicted noun as possible candidates for attachment. At this point, the predicate proximity (or possibly anaphor resolution) bias is stronger than locality, making the parser prefer to attach the RC to the upcoming noun (N_1) based solely on the partial information provided by the second postposition.

(42) head-final RCs
RC N_3 postposition N_2 postposition N_1

An interesting result in the present experiment that was not predicted by any of the models that were considered is the slow reading times of the low condition in regions 3 and 4. Because the RC attachment was presumably successful in region 2 in the low attachment condition, the processing of the two ensuing regions should have been straightforward. We speculate that one explanation could stem from the types of interpretations involved when the RC is attached to the low noun N_3 as compared to the high noun N_1. Consider an English example in which the RC that Mary likes is attached to the high noun bicycle.

(43) The bicycle beside the boy [\textit{\textsubscript{rc} that Mary likes}] …

Because bicycle is already being restricted by the PP beside the boy, it is less likely that the RC further restricts bicycle because, in order to do so, we would have to imagine several bicycles some of which are beside the boy and, among these bicycles beside the boy, it is the case that Mary likes one of them (as in Altmann & Steedman, 1988; Crain & Steedman, 1985). Thus,
restricting an already restricted entity in the discourse may lead to a level of complexity that
the parser may not be willing to entertain in a null context. According to this reasoning,
then, when attached high, the RC is more likely to be interpreted as providing some extra
(non-restrictive) information about the noun. However, if the RC modifies the low noun
boy, then a restrictive interpretation of the RC may obtain. Suppose that this is what is
happening in the Japanese head-final RC construction: the RC is sometimes interpreted as
restrictive in the low attachment, but always as non-restrictive in the other attachments.
In this case, if discourse is more complex for restrictive than non-restrictive information,
the low attachment of the RC might have been particularly taxing in regions 3 and 4 as
the complexity of the restrictive RC was compounded with the complexity of modifying
N2 with N3 and then N1 with N2 according to the intervening postpositions. Therefore,
in the low condition, the initial advantage from locality in region 2 would be replaced by
difficulty with discourse complexity in the following two regions. It is unlikely that discourse
complexity is the factor favouring the high site overall because, according to the previous
reasoning, the middle attachment would also lead to a non-restrictive interpretation of the
RC and therefore this hypothesis could not explain the advantage of the high over the middle
condition in regions 3 and 4. See Kamide et al. (1997, 1998) for a similar slow reading time
after the low attachment is made.

Kamide and colleagues suggested a different explanation for the relative slow reading
times after the attachment is made in the low condition. They proposed that the longer the
RC, the more likely it will be re-attached to the high noun. Supporting evidence comes from
a positive correlation between the length of the RC and the difference between the reading
times of the low and the high conditions in their self-paced reading experiment (Kamide
et al., 1998). In our experiment, the relatively slow reading times in regions 3 and 4 in
the low condition could be due to a late preference that the parser may have to re-attach
longer RCs to the high site. If this were the case, longer RCs in the present experiment
should lead to greater slow-downs. However, in our data, no correlation was found between
the number of characters in the RC and the reading times of the low condition in region
2 (r = -0.06; p = 0.53), region 3 (r = -0.12; p = 0.22) or region 4 (r = -0.01; p = 0.91).
The analysis was conducted taking the low subconditions in Table 3.1.2 (namely, (a), (f)
and (h) separately, because the RCs in these subconditions had different lengths. Similarly, no correlation was found between RC length and the difference in reading times of the low and high conditions in region 2 \((r = -0.04; p = 0.67)\), region 3 \((r = -0.01; p = 0.87)\) or region 4 \((r = -0.04; p = 0.68)\). The differences in residual reading times were calculated separately for the subconditions in Table 3.1.2 as follows: \(a\sim g, f\sim c\) and \(h\sim e\). It is unlikely that the correlations were not significant because too few data points were considered. Each of the two correlation analyses above was conducted with a total of 107 pairs of points (i.e., three subconditions times 36 items, except for one item that had no data available for one subcondition), with the length of the relative clauses varying between 4 and 17 characters \((M = 9.6; SD = 2.9)\). Moreover, comprehension performance was best in the low condition, which does not support a re-attachment explanation, because more confusion (and hence more comprehension errors) might be expected if such re-attachments had been attempted.

3.4 Conclusion

There seem to be two factors at work in the Japanese head-final RC construction with multiple candidate hosts. One is locality favouring the closest site, the other (possibly predicate proximity or anaphor resolution) favours the high site and hence the U-shaped preference curve. On top of these two factors, we tentatively suggest that discourse complexity may also play a part as the type of interpretation for the RC varies.

The U-shaped preference ordering of the candidate sites in the present head-final construction is particularly informative because it supports a parsing framework in which predicted categories are also considered as candidates for attachment even if lexically-realized alternatives may already be available during the processing of the construction. We have argued that such use of partial information is crucial to explain the preference attachment to the high site over the middle site, and that any model of modifier attachment must be able to accommodate such a feature in order to account for the preference ordering observed here.

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Appendix 3-A.

The raw reading times (i.e., without normalizing according to length), trimmed at 4.0 standard deviations (calculated for each condition), are shown in Figure 3.4.

![Graph showing raw reading times for each region.](image)

**Figure 3.4:** Raw reading times for each region.
Appendix 3-B.

The following are the experimental items used in the experiment. All nine subconditions are presented for item 1. For all the other items, only three subconditions are presented as the other six subconditions can be deduced from the pattern presented in Table 3.1.2.

The following were the 12 items that were also analysed separately because they were the most biased towards locally attaching the first PP, according to the off-line norming study:

10, 11, 13, 14, 16, 21, 22, 24, 32, 33, 34 and 35.

1a. 夕べはえていた 机の横の ドアの近くの 犬は、毛むくじゃらで 涼れている。
1b. ノブがこわれている 机の横の ドアの近くの 犬は、毛むくじゃらで 涼れている。
1c. 上の引き出しが壊れている 机の横の ドアの近くの 犬は、毛むくじゃらで 涼れている。
1d. 夕べはえていた ドアの横の 犬の近くの 机は、英国製の アンティークだ。
1e. ノブがこわれている ドアの横の 犬の近くの 机は、英国製の アンティークだ。
1f. 上の引き出しが壊れている ドアの横の 犬の近くの 机は、英国製の アンティークだ。
1g. 夕べはえていた 犬の横の 机の近くの ドアは、かい鍵がついてて 盗難を防ぐ。
1h. ノブがこわれている 犬の横の 机の近くの ドアは、かい鍵がついてて 盗難を防ぐ。
1i. 上の引き出しが壊れている 犬の横の 机の近くの ドアは、かい鍵がついてて 盗難を防ぐ。

2a. その中にはうきがまってあった 盃洗機の 右側の こんろの 反対側の 戸棚は、引き出しが三つついていてかなり幅がある。
2b. 野菜を調理していた こんろの 右側の 戸棚の 反対側の 盃洗機は、昨日消費で買った。
2i. 今、皿を洗っている 戸棚の 右側の 盃洗機の 反対側の 下ろすは、昨日消費で買った。

3a. 私が夕べ寝んだ 鉛筆の近くの ディスケットの 右側の 本は、長くて退屈だった。
3e. 私が夕べ寝れた ディスケットの 右側の 本の 右側の 鉛筆は、教室にあった。
3i. 私がしんを折ってしまった 本の近くの 鉛筆の 右側の ディスケットは、便利で仕事がよかった。

4a. きのうの朝を印が押された 番の 左側の ホッチキスの 前の 畫具箱は、小さくて奇麗だった。
4c. 鉛筆を置いていた ホッチキスの左側の 畫具箱の 前の 番は、ひろがって滑り易い。
4i. コカコーラが一杯入っていた 畫具箱の左側の 番の 前の ホッチキスは、重くて 黒い。

5a. 山田さんが群衆に砲火した 腿の隅の スポンの 後ろの 続は、本物の弾が入っていた。
5e. 椅子でひっかけてやった スポンの隅の 机の後ろの 続は、銃してくれ ギザギザだった。
5i. 山田さんが群衆で賛歌した 机の隅の 鎖の 前ろろの スポンは、 茶色で短すぎた。

6a. きのう食を作っていた 水たまりの 横の 小枝の隅の クモは、小さいが 恐い。
6c. 木から折れて落ちてしまった 小枝の隅の クモの 隅の 水たまりは、 深くて 大きかった。
6i. 子どもがビチャビチャ水を飛び散らしたら クモの 横の 水たまりの 隅の 小枝は、曲がっていて 脆かった。

7a. とてもうるさく鳴っていた ベンの近くの コップの左の 電話は、軽くて使い易い。
7c. 水がこぼれ落ち落ちに入っている コップの近くの 電話の左の ベンは、 古いがとてもよく書ける。
7i. インクがきている 電話の近くの ベンの左の コップは、 製が入っていて壊れている,
8a. 羽毛が一杯まった ベルトの右側の ナイフの反対側の 枠は、 ふかふかしていて 心地よい。
8c. 軽く尖れた ナイフの右側の 枠の反対側の ベルトは、 擦り切れていて 小さい。
8i. いつも川野さんがズボンにしている 枠の右側の ベルトの反対側の ナイフは、 切れ味が 悪い。

9a. すごいスピードで走っていた 道路の横の 標識の前の バスは、 明るい黄色で とても長かった。
9e. 読みにくかった 標識の横の バスの前の 道路は、 狭くて カーブが多い。
9i. 車が止めてあった バスの横の 道路の前の 標識は、 古くて 雨や風で 傷んでいる。

10a. ページが破れている ラジオの近くの コンピューターの隣の 雑誌は、 三十年前ものだが まだそのまま保存されている。
10c. 画面が隣の コンピューターの近くの 雑誌の隣の ラジオは、 楽しませて リラックスさせてくれる。
10i. 五つ放送局が聞く 杂誌の近くの ラジオの隣の コンピューターは、 便利で 面白い。

11a. その部屋を照らしていた ステレオの右側の ソファの後ろの ランプは、 煙々として 高い。
11e. 座り心地よい クッションの ソファの右側の ランプの後ろの ステレオは、 音が大きく 耳障りだ。
11i. うるさい音で なっていた ランプの右側の ステレオの後ろの ソファは、 柔らかいが 丈夫だ。

12a. タペ一晩中聴いていた 蛇の近くの 花の前の カエルは、 とても 機敏で すばしっこい。
12e. 五月に満開に咲いていた 花の近くの カエルの前の 蝶は、 そよ風の中を ひらひらと 飛んでいる。
12i. きなこから出たばかりの カエルの近くの 蝶の前の 花は、 鮮やかで 色彩に富んでいる。

13a. 素晴らしい曲を弾いた 子猫の横の 椅子の左の ギターは、 木製で 美しい音色を出す。
13e. 脚にキャスターが付いている 椅子の横の ギターの左の 子猫は、 毛がサラサしていて 愛らしい。
13i. 毛氷晶とじゃれている ギターの横の 子猫の左の 椅子は、 柔らかくて 座り心地がよい。

14a. ハスの葉が浮いていた 道の前の 家の右側の 池は、 風で 波立っている。
14e. 古れんができた 湖面がある 家の前の 池の右側の 道は、 くねくねと 曲がっていて 狭い。
14i. 平野さんが歩き慣れた 池の前の 道の右側の 家は、 秋もって 倒れかけていた。

15a. 中村さんが木曜日にしていた ほうきの左の ティーポットの後ろの エプロンは、 汚れていて シミが付いている。
15e. ストーブの上で 湯き立っていた ティーポットの左の エプロンの後ろの ほうきは、 ブランは 鮮が使い易い。
15i. 中村さんが 床を掃いた エプロンの左の ほうきの後ろの ティーポットは、 日本製で 美味しいお茶がいわれる。

16a. 自分の 嘆き声で犬を 追い立てた 帽子の近くの 靴の反対側の 猫は、 年寄りで 愛想が悪い。
16e. 私が 右足に 付けていた 靴の近くの 猫の反対側の 帽子は、 上に大きな羽が 付いている。
16i. 私が頭 にかぶっていた 猫の近くの 帽子の反対側の 靴は、 キメの細かい革で できている。

17a. 自分の 父親に微笑みかけた ベッドの隣の ボールの前の 男の子は、 優しくて 朗らかだ。
17e. その子供が池に投げたような 球の隣の 男の子の前の ベッドは、 おんぶがよくて 小さい。
17i. 犬が 寝ていた 男の子の隣の ベッドの前の ボールは、 ゴム製で よく弾む。

18a. マリーが お化粧のために切った 手紙の近くの スプーンの後ろの りんごは、 つるつる光っていて 赤い。
18e. マリーがヨーグルトをふくったスプーンの近くのりんごの手紙は、長くて詳しく書かれている。
18f. マリーが息子叔父宛書いたりんごの手紙の後ろのスプーンは、輝が入っていって欠けている。

19a. 観光客に親しむつづくプールの隣の桜の左側のライオンは、大きくて美しい。
19c. 銀で出来ている桜の隣のライオンの左側のプールは、大きくて美しい。
19b. 観光客が使いだライオンの隣のプールの左側の桜は、大きくて美しい。

20a. 学校まで乗ったおりの横の人の後ろの自転車は、きれいで大きかった。
20e. バーティーで会った人の横の自転車の後ろのおりは、きれいで大きかった。
20i. 枝がおれている自転車の横のおりの人の後ろは、きれいに大きかった。

21a. 姉が描いたテーブルの隣のテレビの右側の絵は、高くて小さかった。
21e. うるさい音がしているテレビの隣の絵の右側のテーブルは、高くて小さかった。
21i. 私がタベ食事をした絵の隣のテーブルの左側のテレビは、高くて小さかった。

22a. お茶がいっぱい入っている写真の横の新聞の反対側の茶碗は、古くて黄色んでいた。
22c. うその話が書いてある新報の横の茶碗の反対側の写真は、古くて黄色んでいた。
22i. 昨日焼き直した茶碗の横の写真の反対側の新聞は、古くて黄色んでいた。

23a. ワインを急冷凍した缶切りの隣の流しの左側の冷蔵庫は、古くて使いにくいかった。
23e. 我々が食器洗いをした流しの隣の冷蔵庫の左側の缶切りは、古くて使いにくいかった。
23i. 砂を必要のある冷蔵庫の缶切りの左側の流しは、古くて使いにくいかった。

24a. 木に登った街灯の隣の郵便受けの反対側のりすは、小さくて可爱かった。
24e. 郵便受けの隣のりすの反対側の街灯は、小さくて可爱かった。
24i. 道を明るく照らしているりすの隣の街灯の反対側の郵便受けは、小さくて可爱かった。

25a. 女の子にきしゃやいたコピー機の近くの壁の横の図書館員は、大きくて険かった。
25c. コンクリートで出来ている壁の近くの図書館員の横のコピー機は、大きくて険かった。
25i. 私が以前論文を複写した図書館員の近くのコピー機の横の壁は、大きくて険かった。

26a. 清掃婦がほうきではいたアライグマの後ろのバケツの反対側の砂は、茶色できれいだった。
26e. 水がいっぱい入っているバケツの後ろの砂の反対側のアライグマは、茶色できれいだった。
26i. 追いかけて砂の後ろのアライグマの反対側のバケツは、茶色できれいだった。

27a. 警笛を吹いた車の横の木の右側の警察官は、美しくて有名だった。
27c. 葉っぱが落ちてしまった木の横の警察官の右側の車は、美しくて有名だった。
27i. パックミラーがとれている警察官の車の右側の木は、美しくて有名だった。

28a. 弦が切れしたスズメの左側のトランペットの前のハープは、古くて小さかった。
28e. 吹き口がなくなっ たトランペットの左側のハープの前のスズメは、古くて小さかった。
28i. 花子がすわったハープの左側のスズメの前のトランペットは、古くて小さかった。

29a. 田中さんに書いた鏡の横に練り歯磨きの反対側のメモは、新しくて白かった。
29e. 虫歯を防ぐ練り歯磨きの横のメモの反対側の鏡は、新しくて白かった。
29i. 光っているメモの横の鏡の反対側の練り歯磨きは、新しくて白かった。
30a. まだ飲んでいない スプーンの後ろの ステーキの近くの お茶は、高く て 有名だ。
30c. こんがりと焼いてある ステーキの後ろの お茶の近くの スプーンは、高く て 有名だ。
30i. 毎日で出来ている お茶の後ろの スプーンの近くのステーキは、高く て 有名だ。
31a. ヒールが高い 上着の隣の 傘の右側の ブーツは、古くて 破れていた。
31c. 梢が奇麗な 傘の隣の ブーツの右側の 上着は、古くて 破れていた。
31i. さい生地で出来ている ブーツの隣の 上着の右側の 傘は、古くて 破れていた。
32a. 消えてしまった バラの前の 彫像の左側の ローソクは、大きくて きれいだった。
32c. 腰が一本おろっている 彫像の前の ローソクの左側の バラは、大きくて きれいだった。
32i. きれいに咲いている ローソクの前の バラの左側の 彫像は、大きくて きれいだった。
33a. はさみが一つしかない タオルの近くの ピンの前の カニは、小さくて 赤かった。
33c. コーラが入っている ピンの近くの カニの前の タオルは、小さくて 赤かった。
33i. 洗濯した カニの近くの タオルの前の ピンは、小さくて 赤かった。
34a. くぎを打った 鰯の横の ドライバーの後ろの カナズチは、新しくて 使いやすかった。
34c. ケージをした ドライバーの横の カナズチの後ろの 鰯は、新しくて 使いやすかった。
34i. 板を切った カナズチの横の 鰯の後ろの ドライバーは、新しくて 使いやすかった。
35a. ガットのはりかえが必要な ロッカーの前の トレーナーの右側の ラケットは、新しくて 高かった。
35c. 袖が長い トレーナーの前の ラケットの右側の ロッカーは、新しくて 高かった。
35i. 剣がかかっている ラケットの前の ロッカーの右側の トレーナーは、新しくて 高かった。
36a. 10分おくれている マグカップの隣の カタログの反対側の 時計は、高く て 重かった。
36c. 200ページもある カタログの隣の 時計の反対側の マグカップは、高く て 重かった。
36i. コーヒーを入れている 時計の隣の マグカップの反対側の カタログは、高く て 重かった。