1. Introduction

Studies in various languages have been conducted to understand the processing of ambiguous relative clauses (RCs) like the following (from Cuetos & Mitchell, 1988).

(1) the servant of the actress [RC who was on the balcony]

The RC can be associated with servant (the high noun in the tree structure) or actress (the low noun). Average preferences have been shown to vary across languages. For example, native speakers of English preferentially attach the RC to the low noun, whereas speakers of Dutch, French, Spanish among other languages prefer the high noun (Brysbaert & Mitchell, 1996; Cuetos & Mitchell, 1988; Zagar, Pynte & Rativeau, 1997; see http://www.lingua.tsukuba.ac.jp/etm/rc, for a more comprehensive list of languages tested).

The high preference in various languages goes against a large literature on locality preferences according to which the closest candidate site to the phrase being attached is favored (e.g., Frazier, 1987; Gibson, 1998; Kimball, 1973). Thus, RC attachment has been used to investigate how the processing mechanism interacts with different grammars, in particular, how locality preferences are modulated by grammatical parameterizations. (See Table 1 for a partial list of proposals.) However, most studies thus far have dealt with European languages, and therefore their scope is often limited to postnominal RCs.

Results on prenominal RCs in Japanese have been contradictory. When shown ambiguous RCs that allow both interpretations (as in (2) from Kamide & Mitchell, 1997, Experiment 1), Japanese readers prefer the high noun (see also Hirose, 2001).

(2) Dareka-ga [RC barukonii-ni iru] joyuu-no mesitsukai-o utta. somebody-nom balcony-loc is actress-gen servant-acc shot

‘Somebody shot the servant of the actress who is on the balcony.’

In contrast, when reading times were measured for unambiguous sentences (disambiguated through plausibility manipulations), low attachment sentences were read faster.
i. alternation between relative pronouns and complementizers in RCs (e.g., who/that was on the balcony; Cuetos & Mitchell, 1988)

ii. the existence of an alternative construction (colonel’s daughter) together with Gricean maxims (Frazier & Clifton, 1996; Thornton, Gil & MacDonald, 1998)

iii. the subject is not allowed to appear after a direct object as in VOS (Gibson et al., 1996)

iv. adverbs are not allowed to intervene between the verb and its direct object (Miyamoto, 1999)

v. prosodic contours in the language disfavor the insertion of a pause between the head nouns and the RC (Fodor, 1998, 2002)

Table 1  Factors that may explain the low attachment preference in English.

than their high attachment versions at the low noun N₁, the genitive marker and the high noun N₂ in (3a), but that trend was reversed at sentence end (Kamide & Mitchell, 1997).

(3) a. RC | N₁ | gen | N₂ | …  (Kamide & Mitchell, 1997, Experiment 2)

b. RC | N₁-gen | N₂ | …  (Kamide et al., 1998)

The initial advantage for local attachment in the reading time experiment may have been a segmentation artefact as the genitive marker was shown separated from N₁ (bars in (3) indicate the segmentations used in the self-paced reading presentations). When N₁ is read in (3a), there is no indication that another head noun is coming, thus the segmentation may have inadvertently boosted the preference for the low noun by making it the only candidate available initially. Another experiment partially supports this interpretation. When N₁ is shown together with the genitive marker as in (3b), there was no statistically reliable difference at that point, although the low attachment sentences were numerically faster (Kamide et al., 1998; but cf. Miyamoto et al., 1999, for a statistically reliable advantage for low attachment when locative postpositions are shown with N₁).

In order to address the segmentation controversy and further investigate the time course of RC attachment in Japanese, a series of experiments were conducted.

2.   Experiment 1

In this first experiment, we address the segmentation issue.

2.1.   Method

Twenty undergraduates at Kanda University of International Studies were paid for their
participation. A non-cumulative moving-window self-paced reading setup (Just, Carpenter & Woolley, 1982) presented sentences one at a time on a single line. Each sentence was followed by a comprehension question presented on a new screen without feedback.

2.1.1. Materials

Twenty-four sets of sentence pairs (from Kamide & Mitchell, 1997, Experiment 2) were used in the experiment. The following is an example set.

(4) a. High attachment RC
   
   R1: Hoosekibako-no sumi-ni nokotteita | hannin-no simon-o | ...
   
   "jewelry-box-gen corner-loc remained criminal-gen fingerprint-acc"
   
   ‘the fingerprint of the criminal (that) remained in the corner of the jewelry box’

b. Low attachment RC
   
   R1: Gojuudai dansei-to suiteisareru | hannin-no simon-o | ...
   
   "50s male-as supposed criminal-gen fingerprint-acc"
   
   ‘the fingerprint of the criminal (who) is supposed to be a male in his 50s’

c. Matrix clause
   
   R3: 
   
   "The police somehow found..."

The segmentation (indicated with vertical bars) shows the two head nouns together in region 2 (labelled R2), which makes both sites available simultaneously and avoids giving an artificial advantage to the low noun. Note that the low noun still has an advantage as it is going to be read first, but this is not an experimental artefact, rather it is a consequence of the word order in Japanese.

Two lists were created by distributing the test items according to a Latin square design and intermixing 40 filler items in pseudo-random order so that at least one filler intervened between consecutive test items. Each participant saw only one list.

2.1.2. Norming Study

To guarantee that the plausibility manipulation (that determines the RC attachment) was effective, 36 native speakers of Japanese who did not take part in the main study rated the
naturalness of the RC attachment portions of the sentences from 1 (*natural*) to 5 (*strange*). For the set in (4), the following four conditions were created.

(5)  

a. High noun as part of the High RC (HH for short; plausible)  
Simon-wa hoosekibako-no sumi-ni nokotteita.  
fingerprint-top jewelry-box-gen corner-loc remained  
‘The fingerprint remained in the corner of the jewelry box.’

b. Low noun as part of the Low RC (LL; plausible)  
Hannin-wa gojuudai dansei-to suiteisareru.  
criminal-top 50s male-as supposed  
‘The criminal is supposed to be a male in his 50s.’

c. High noun as part of the Low RC (HL; implausible)  
Simon-wa gojuudai dansei-to suiteisareru.  
fingerprint-top 50s male-as supposed  
‘The fingerprint is supposed to be a male in his 50s.’

d. Low noun as part of the High RC (LH; implausible)  
Hannin-wa hoosekibako-no sumi-ni nokotteita.  
criminal-top jewelry-box-gen corner-loc remained  
‘The criminal remained in the corner of the jewelry box.’

Analyses of the ratings for the four conditions (HH 1.49; LL 1.43; HL 3.96; LH 4.45) revealed that the plausible conditions (LL and HH) were more plausible than the implausible conditions ($P_s < 0.01$). The two plausible conditions did not differ ($F_s < 1$) as is desirable in this kind of experiment and it attests the care with which the original items (Kamide & Mitchell, 1997) were created.

However, the LH condition was rated more implausible than the HL condition ($P_s < 0.01$). Ideally, those two conditions should not differ but this is a difficult difference to control for when creating the items. These ratings are important because they may indicate how much the alternative interpretation competes with the intended interpretation during the online experiment (e.g., LH corresponds to: when reading the high RC, how natural it is for the RC to be attached to the low noun), and the different ratings for LH and HL will have to be taken into consideration when interpreting the reading time results.

2.2. Results

Comprehension performance did not differ between the two conditions (Low 85.9%; High 86.7%; $F_s < 1$).
Reading time results were as follows. There was no difference in the first region \((F_s < 1)\). In region 2 (the two head nouns), the high condition was read more slowly than the low condition \((F_1(1,19) = 28.7, P < 0.01; F_2(1,23) = 13.2, P < 0.01)\). In region 3, the high condition was faster than the low condition in the participant analysis \((F_1(1,19) = 5.1, P < 0.05; F_2 < 1)\). In region 4, the high condition was reliably faster in the participant analysis \((F_1(1,19) = 11.3, P < 0.01; F_2(1,22) = 3.5, P < 0.08; one item was not included in the item analysis of this region because all its data points for the low condition had to be eliminated, e.g., because of mistakes to answer the comprehension question).

### 2.2.1. Correlation Analyses

In order to determine whether differences in plausibility accounted for the reading time patterns, a correlation analysis was conducted. For each region, the reading time differences \((\text{Low} – \text{High})\) for each item did not correlate with the rating differences in the norming study (with LL – HH or with HL – LH; all \(P_s > 0.13\); all \(r^2_s < 0.1\)). Therefore, despite the plausibility difference between HL and LH, the lack of correlation suggests that reading times were not affected by the plausibility of the competing interpretation.

Kamide et al. (1998) reported a reliable correlation between reading times and length of the RC. Thus, a similar analysis was conducted. A linear correlation between reading time differences for each item \((\text{Low} – \text{High})\) and length of the RC in number of characters yielded no reliable results for regions 1, 2 and 4 \((P_s > 0.35)\). In region 3, there was a reliable correlation \((r^2 = 0.24, P < 0.05)\), so that the longer the RC the greater the \((\text{Low} – \text{High})\) reading time difference. This is compatible with the claim that implicit prosodic contours (i.e., prosody computed for text read in silence) influence attachment decisions (Fodor, 1998, 2002; see Experiment 2 below).

### 2.3. Discussion

The faster reading times for the low attachment condition in region 2 confirm the initial preference that readers have for this type of attachment. Given the coarse segmentation used, it is unlikely that this was the result of segmentation artefacts, in particular, it cannot be due to the late availability of the high noun. The question then is why the initial preference for low attachment turns into a high attachment preference at sentence end (as attested by the reading times in the last region of the present experiment as well as in Kamide & Mitchell, 1997; Kamide et al., 1998; and in questionnaires reported by Hirose, 2001; Kamide & Mitchell, 1997). The following sections report the preliminary results of two experiments investigating two possible factors, namely, prosody and word order.

### 3. Experiment 2

In this experiment, prosody effects on RC attachment were investigated.
Literature on working memory reports that the continuous utterance of nonsense syllables prevents rehearsal in the phonological loop (inner speech suppression, ISS) and eliminates phonological effects in the recall of lists of words (e.g., effects of length and of confusability because of similarity; see Baddeley, 1990, for a summary and references). If implicit prosody is dependent on the phonological loop, it should be disrupted by ISS (see Slowiaczek & Clifton, 1980). By comparing attachment preferences while reading in silence and with simultaneous vocalization, prosodic effects can be isolated.

One possible prediction is that there is a locality preference in general (i.e., a preference for the closest candidate site; Frazier, 1987; Gibson, 1998; Kimball, 1973; inter alia), and that prosodic contours modulate locality based on the lengths of the modifier and the head. For the RCs investigated, length can favor the high noun for two reasons (Fodor, 1998, 2002). First, if the RC is long, a pause is more likely to be inserted between the RC and the head nouns, thus weakening the locality preference. Second, the high noun is always longer than the low noun as it includes the low noun as a modifier (e.g., for (1), the low noun is *the actress*, whereas the high noun is not just *servant*, but rather *the servant of the actress*). If readers have a preference to keep the length of the RC and the length of its head equal (*the same-size-sister constraint*, Fodor, 1998), then the longer the RC, the more likely for it to be attached to the high noun. The same-size sister constraint could be responsible for the correlation reported in Experiment 1 between RC length and reading time in region 3.

If ISS prevents implicit prosody from being computed, then pauses and length effects should be eliminated, and with locality being the only factor at play, the low noun should be favored throughout the sentence.

### 3.1. Method

The test sentences and the setup were the same as the ones used in Experiment 1, except that there were two sessions. In one session, participants read 12 test items plus 42 filler sentences in silence, and, in the other session, they read a different set of 12 test items plus 42 fillers while repeating nonsense syllables (*ru* or *ne*) aloud. This created a $2 \times 2$ design (Silence/ISS × High/Low). Order of the tasks was counterbalanced across participants, who were monitored throughout both sessions to ensure that they followed the instructions appropriately by reading in silence or repeating the nonsense syllables at a rapid constant pace (approximately three times per second).

Thirty-three native speakers of Japanese from the Nara Institute of Science and Technology (NAIST) were paid to participate in the study, none of which had participated in the first experiment or in the norming study. One participant’s data were eliminated from further analysis because of low comprehension performance (less than 70%).
3.2. Results

There were no reliable effects in the comprehension performance of the four conditions (between 87.5% and 92.7%) except for a main effect of task with the ISS conditions reliably worse than the Silence conditions in the item analysis ($F_1(1,31) = 1.77, p > 0.19$; $F_2(1,23) = 5.93, p < 0.05$; see Slowiaczek & Clifton, 1980, for similar trends).

Reading time results were as follows. There were no reliable differences in region 1 (the RC; all $Ps > 0.17$).

In region 2 (the head nouns), there were main effects of task (ISS faster than Silence, $F_1(1,31) = 16.2, P < 0.01$; $F_2(1,23) = 21.6, P < 0.01$) and of attachment (High slower than Low; $F_1(1,31) = 17.2, P < 0.01$; $F_2(1,23) = 12.2, P < 0.01$). There was no interaction (ISS: High – Low, 227 ms; Silence: High – Low, 470 ms; $F_1(1,31) = 1.7, P < 0.2$; $F_2(1,23) = 2.1, P < 0.16$).

In region 3 (the first part of the matrix clause), the ISS conditions were slower than the Silence conditions in the item analysis ($F_1(1,31) = 3.0, P < 0.1$; $F_2(1,23) = 5.9, P < 0.05$). The High conditions were numerically faster than the Low conditions but the difference was not reliable ($Fs < 1$). There was no interaction ($Fs < 1$).

In region 4 (the matrix predicate), there was no effect of task ($Fs < 1$) nor interaction ($F_1 < 1; F_2(1,23) = 1.3, P < 0.27$). The High conditions were faster than the Low conditions ($F_1(1,31) = 13.1, P < 0.01; F_2(1,23) = 5.3, P < 0.05$).

3.2.1. Correlation Analyses

Linear regression analyses between RC length in number of characters and difference in reading times (Low – High) were conducted. For the Silence conditions, results were as follows. In region 1, RC length correlated marginally with reading time difference ($r^2 = 0.16, P < 0.06$). There were no reliable correlations in the remaining regions ($Ps > 0.3$). In the ISS conditions, there was no reliable correlation in any region ($Ps > 0.7$).

Numerically, the tendency for length effects were more apparent in the Silence conditions than in the ISS conditions, but we did not replicate the correlation in region 3 found in Experiment 1.

3.3. Discussion

There was no interaction between attachment (High/Low) and task (Silence/ISS), and the same pattern as in Experiment 1 was observed, namely, an initial bias towards Low attachment, and a High attachment advantage at the end. This suggests that ISS does not affect attachment and therefore prosody is unlikely to be the factor responsible for the preferences observed, in particular, it is unlikely to explain the high attachment preference at sentence-end.

Although there was no correlation between reading times and RC lengths in the ISS
conditions, that was also the case for the ISS conditions. Therefore, there is no guarantee that the vocalization task achieved its intended purpose of eliminating implicit prosody. We are currently considering ways of addressing this point.

4. **Experiment 3**

In this experiment, the effect of word order on RC attachment was investigated.

4.1. **Method**

The experiment setup was the same as the one used in Experiment 1. Thirty-five native speakers of Japanese from NAIST were paid to participate. Three participants’ data were eliminated because of low overall comprehension performance (72% or less).

4.1.1. **Materials**

Apart from scrambled sentences (as in (4)), canonical versions were also included in a 2×2 design (Canonical/Scrambled × High/Low). The two sentences in (6) are an example of a Canonical pair (the scrambled versions can be obtained by moving regions 2 and 3 to the front of the sentence as in 2-3-1-4). The 24 sets of items of Experiment 1 were used with some of the matrix clauses modified to make their subjects implausible as part of the RCs.

(6)  

a. High attachment

   R1 | R2
   Satsujinka-wa | hoosekibako-no sumi-ni nokotteita | ...
   homicide-dept-top | jewelry-box-gen | corner-loc | remained

b. Low attachment

   R1 | R2
   Satsujinka-wa | gojuudai dansei-to suiteisareru | ...
   homicide-dept-top | 50s | male-as | supposed

c. Remaining regions

   R3 | R4
   hannin-no | simon-o | nantoka mitsukedasita.
   criminal-gen | fingerprint-acc | somehow | found

High condition: ‘The homicide department somehow found the fingerprint of the criminal (that) remained in the corner of the jewelry box.’

Low condition: ‘The homicide department somehow found the fingerprint of the criminal (who) is supposed to be a male in his 50s.’
The test items were distributed into four lists according to a Latin Square design and were shown in pseudo-random order interspersed with 54 filler items.

4.1.2. Norming Study

In the canonical conditions, before the head nouns are read, the tendency is for the matrix subject to be interpreted as part of the RC leading to a garden path. At that point, plausibility is the only clue that this is incorrect. Thus, 28 native speakers of Japanese rated the plausibility of fragments like the following with the matrix subject and each RC.

(7) a. Matrix subject as part of the high attachment RC

Satsujinka-wa hooseikako-no sumi-ni nokotteita
homicide-dept-top jewelry-box-gen corner-loc remained
`The homicide department remained in the corner of the jewelry box.'

b. Matrix subject as part of the low attachment RC

Satsujinka-wa gojuudai dansei-to suiteisareru
homicide-dept-top 50s male-as supposed
`The homicide department is supposed to be a male in his 50s'

The ratings for (7a) (4.42; scale from 1 = natural to 5 = strange) and for (7b) (4.48) did not differ \( F_1(1,27) = 1.34, P < 0.26; F_2 < 1 \). Therefore, the likelihood of the matrix subject being interpreted as part of the RC is equally low for the two types of RCs.

4.2. Results

There was no reliable effect in the comprehension performance for the four conditions (between 87.5% and 91.7%; all \( F_s < 1 \)).

There were no reading time differences for the matrix subject between the two Canonical conditions or between the two Scrambled conditions (all \( F_s < 1 \)). There was no reliable difference at the RC region for the four conditions (all \( F_s < 1 \)).

In the region containing the two head nouns, there was an interaction between word order (Canonical/Scrambled) and attachment (High/Low; \( P_s < 0.05 \)). For the Scrambled conditions, Low was faster than High in the participant analysis \( (F_1(1,31) = 4.77, P < 0.05; F_2(1,23) = 3.77, P < 0.07) \), whereas for the Canonical conditions, High was numerically faster than Low \( (F_s < 1.2) \). There was also a main effect of word order as the Scrambled conditions were read more slowly than the Canonical conditions \( (P_s < 0.01) \); this is likely to be a position effect as fewer regions had been read in the Scrambled conditions at that point (readers tend to speed up as they read more words).

In the matrix predicate region, there was a main effect of attachment as the High
conditions were faster than the Low conditions ($P < 0.01$). There was a main effect of word order as the Scrambled conditions were faster than the Canonical conditions ($F < 0.01$); this effect should be expected as the Canonical sentences involve a self-embedding configuration which is known to cause processing difficulties (Chomsky & Miller, 1963). There was no interaction ($F < 1$).

4.3. Discussion

The present experiment provides evidence that word order influences attachment decisions as attested by the interaction at the head nouns. One possible explanation is that in the scrambled conditions, the RC is initially interpreted as being a main clause and the mistake is only identified at the head nouns. In the canonical conditions, in contrast, the matrix subject is incompatible with the RCs, providing an early indicator for the higher clause. Thus, in the scrambled conditions, the higher predicate is not predicted until the head nouns are seeing, whereas in the canonical conditions the matrix subject may create the expectation for the matrix predicate earlier. It has been suggested that the matrix predicate is important in RC attachment decisions because the salience of the high noun is derived from the fact that this noun is the head of an argument of the matrix predicate (e.g., in (4), ‘fingerprint’ is the head of the direct object of ‘found’, whereas ‘criminal’ is not directly related to this verb; Frazier, 1990; Gibson et al., 1996). Thus, the late prediction of the matrix clause in the Scrambled sentences may weaken the salience of the high noun at first.

In the Canonical conditions, the High condition was numerically faster than the Low condition at the head nouns, but the difference was no statistically reliable. There are a number of possibilities that need to be considered for the reading time patterns in this region. First, the High is in fact faster than the Low condition at that point, but there was not enough statistical power. Second, although the matrix subject was equally implausible as part of both types of RCs (as attested by the norming study), it is conceivable that the NP was initially interpreted as part of the RCs, and that the ensuing reanalysis process necessary to expel the subject from the RC makes the reading times for the High and Low conditions indistinguishable. A third possibility is that this reanalysis process is in fact responsible for the interaction between attachment and word-order at the head nouns, and therefore the timing of the prediction of the matrix predicate per se is not critical. These three possibilities are being examined in ongoing work.

5. Conclusion

Three self-paced reading experiments and two plausibility studies were reported in order to address various issues in the attachment of ambiguous relative clauses with two potential modifiees in Japanese. Using a coarse-grained segmentation, Experiment 1 confirmed the initial low attachment preference and its reversal at sentence-end (as in Kamide & Mitchell, 1997). The preliminary results of two experiments suggest future directions. In Exper-
iment 2, no influence of prosodic contours on RC attachment was found. Experiment 3 detected an interaction between word order (Scrambled/Canonical) and attachment, which is compatible with the claim that awareness of an upcoming matrix predicate is critical in determining attachment preferences.

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