An ERP study of the processing of subject and object relative clauses in Japanese

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Abstract

Using reading times and event-related brain potentials (ERPs), we investigated the processing of Japanese subject/object relative clauses (SRs/ORs). English ORs take longer to read (King & Just, 1991) and elicit left-lateralized/bilateral anterior negativity (LAN) between fillers and gaps (King & Kutas, 1995), which is largely attributed to a longer filler-gap distance. In contrast to English, gaps in Japanese relative clauses precede their fillers, and the linear gap-filler distance is longer in SRs than in ORs. Nevertheless, Japanese ORs take longer to read (Ishizuka, Nakatani, & Gibson, 2003; Miyamoto & Nakamura, 2003), perhaps because in both English and Japanese, ORs involve a longer structural filler-gap/gap-filler distance in their syntactic representations (O'Grady, 1997). We investigated how gap-filler association in Japanese would compare to filler-gap association in English, and whether it is linear or structural distance that determines comprehension difficulty. The results showed higher processing costs from the head noun to the sentence-end for ORs than SRs in both reading times and ERPs. Our data also suggest that gap-filler association in Japanese relative clauses involve a long-lasting integration process after the filler, as indexed by the continuous centro-posterior positivity to ORs (cf. Kaan, Harris, Gibson, & Holcomb, 2000). Finally, both ERP and reading time data seem more consistent with a structural distance account than a linear distance account, at least for Japanese relative clauses.
Acknowledgements

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Introduction

The fundamental question addressed in this paper is how syntactically distinct languages are processed in the brain. By investigating such a question, we hope to find both language-universal and language-specific aspects of sentence comprehension and thereby to narrow the gap between linguistic and cognitive neuroscientific approaches to language. Event-related brain potentials (ERPs) are useful in this endeavor, as they reveal millisecond-by-millisecond changes in neural activity during language comprehension.

This study investigates the processing of Japanese subject and object relative clauses using both self-paced reading times and ERPs, and compares the results to similar studies done in English and other languages. Consider subject and object relative clauses in English, as illustrated below in (1). The sentence fragment in (1a) is called a subject relative (SR) because the head noun the reporter is the subject of the relative clause (RC) who attacked the senator, i.e., the reporter is the one who attacked the senator. The sentence fragment in (1b) is called an object relative (OR) because the head noun the reporter is the object of the RC who the senator attacked, i.e., the senator attacked the reporter.

1. a. Subject relative (SR)

   head noun \[\text{the reporter} \quad \text{who} \quad \text{attacked the senator}\]

   \[\text{FILLER GAP}\]

   b. Object relative (OR)

   the reporter \[\text{who the senator attacked} \quad \text{...}\]

   \[\text{FILLER GAP}\]
A large number of studies using various methodologies have shown that ORs are harder to process than SRs in English (e.g., reading times: King & Just, 1991; eye-tracking: Traxler, Morris, & Seely, 2002; ERPs: King & Kutas, 1995; fMRI: Caplan et al., 2001). The explanation for this is often tied to the notion of filler-gap dependencies. In (1), the displaced wh-element *who* is called a *filler* while the canonical position in the sentence for an element with its grammatical function (e.g., subject and object) is called a *gap*, and they are said to be dependent on each other, as the interpretation of a filler involves associating it with its gap (cf. Fodor, 1989). While the filler and its gap are immediately adjacent to each other in SRs, there are words intervening between them in ORs, and this distance between the filler and its gap is said to be the source of difficulty (e.g., Gibson, 1998, 2000). Simple distance between words in a sentence is conventionally called *linear distance*. Alternatively, distance between a filler and its gap can be characterized in another way, in terms of hierarchical syntactic structure, as shown in Figure 1 (e.g., Chomsky, 1981). The object gap position is more deeply embedded in the phrase structure than the subject gap position, so there are more syntactic nodes between the filler and its gap in ORs than in SRs. This kind of distance is conventionally called *structural distance*, and could be another source of comprehension difficulty in ORs (O’Grady, 1997).

(Figure 1 about here)

RCs in Japanese differ from those in English in several important ways. Some of those differences arise because of the differences in the two languages’ basic word orders. With respect to RCs specifically, Japanese RCs are prenominal (the RC precedes its head noun) as shown in (2). In English, in contrast, relatives are postnominal, as illustrated above in (1). Another difference between the two languages is that Japanese has no overt relativizers while English has relative pronouns such as *who* and *that*. Thus, instead of a relative pronoun, it is the
head noun that functions as the filler in word-by-word sentence processing in Japanese. The consequence of these differences in Japanese and English is that a gap precedes the head noun that fills it in Japanese, while a gap follows the relative pronoun that fills it in English. As will be discussed later, this word order difference is likely to lead to important differences in how RCs are processed in Japanese and English.

(2) a. Subject relative (SR) in Japanese

\[ \text{relative clause (RC)} \quad \text{head noun} \]

\[ \quad \text{GAP} \quad \text{FILLER} \]

\[ \text{‘the reporter [(who) __ attacked the senator]’} \]

b. Object relative (OR) in Japanese

\[ \text{relative clause (RC)} \quad \text{head noun} \]

\[ \quad \text{GAP} \quad \text{FILLER} \]

\[ \text{‘the reporter [(who) the senator attacked __]’} \]

Another feature of Japanese that is important here is that it allows pro-drop, i.e., the complete omission of words that would instead be pronominalized in English. Subject pro-drop (3a) is much more common than object pro-drop (3b) in Japanese (Ueno & Polinsky, submitted), but both can occur in certain kinds of discourse.
(3) a. Subject pro-drop sentence

pro 議員を 非難した
pro giin-o hinanshita
pro senator-ACC attacked
‘(I/you/he/she/we/they) attacked the senator’

b. Object pro-drop sentence

議員が pro 非難した
giin-ga pro hinanshita
senator-NOM attacked
‘The senator attacked (me/you/him/her/us/them)’

Furthermore, Japanese has a clause type called fact-clause, which is a clause that modifies certain nouns such as ‘fact’, ‘news’, and ‘rumor’ without a gap, as in ‘the fact that the reporter attacked the senator’. Following the basic word order of Japanese, these fact-clauses are also prenominal, as shown in (4). Notice that just as there is no overt relativizer in Japanese RCs, there is also no complementizer in Japanese fact-clauses, i.e., there is no word equivalent to the English complementizer that.

(4) Fact-clause

[記者が 議員を 非難した] 事実
[kisha-ga giin-o hinanshita] jijitsu
[reporter-NOM senator-ACC attacked] fact
‘The fact [(that) the reporter attacked the senator]’

Fact-clauses also differ from their English parallel in that they allow pro-drop, as shown in (5).
(5) a. Fact-clause with subject pro-drop

\[
\begin{align*}
[\text{pro} & \quad \text{議員を} \quad \text{非難した}] \quad \text{事実} \\
[\text{pro} & \quad \text{giin-o} \quad \text{hinanshita}] \quad \text{jijitsu} \\
[\text{pro} & \quad \text{senator-ACC} \quad \text{attacked}] \quad \text{fact}
\end{align*}
\]

‘The fact [(that) (I/you/he/she/we/they) attacked the senator]’

b. Fact-clause with object pro-drop

\[
\begin{align*}
[\text{議員が} & \quad \text{pro} \quad \text{非難した}] \quad \text{事実} \\
[\text{giin-ga} & \quad \text{pro} \quad \text{hinanshita}] \quad \text{jijitsu} \\
[\text{senator-NOM} & \quad \text{attacked}] \quad \text{fact}
\end{align*}
\]

‘The fact [(that) senator attacked (me/you/him/her/us/them)]’

Taken together, the combination of the prenominal position of noun-modifiers such as RCs and fact-clauses, the absence of overt relative markers, and the possibility of pro-drop means that there can be temporary ambiguity about whether a sequence of words constitutes a RC, a simple mono-clausal sentence, or a fact-clause. In other words, a RC like (2a) or (2b) could be initially interpreted as a simple mono-clausal sentence as in (3a) or (3b) or as a fact-clause as in (5a) or (5b). It is only at the point when the head noun appears that it becomes clear that the word string must constitute a RC modifying the head noun that has appeared. That these words constitute a noun-modifying clause is signaled by the fact that a noun follows a verb, while verbs are always clause-final in Japanese. In other words, if a verb is followed by a noun, that verb must be the end of a prenominal clause modifying that noun. The possibility that the sentence is a fact-clause like (5a) or (5b) would be ruled out at the head noun position since the noun is not a ‘fact’-type noun.

These differences between Japanese and English RCs have several consequences for how they could be comprehended. First, as discussed above, Japanese RCs are temporarily ambiguous. In English, comprehenders would typically know that a sequence of words is part of a RC because many cues, such as a relative pronoun immediately following a head noun, are
available early in the sentence. In contrast, Japanese comprehenders may not know that there is a RC noun structure until its very last word, the head noun, appears. Another difference is that in Japanese, it is SRs that involve a longer linear gap-filler distance as shown in (2), while in English it is ORs that involve a longer linear filler-gap distance, as shown in (1). While there are many differences between Japanese and English RCs, they are argued to have similar hierarchical structures, as shown in Figure 2. In the Japanese structures, there is a covert operator (an entity that identifies the gap) instead of a relative pronoun coindexed with both the head noun and the gap (e.g., Kaplan & Whitman, 1995)\(^3\), but otherwise the structure is the same in both languages. In spite of the fact that the left-to-right order of the words in the phrase structure differs between English and Japanese, the hierarchical relationship of the syntactic configuration is the same, which means that the object gap position is more deeply embedded than the subject gap position. Thus, despite surface differences between the two languages that result in a longer linear distance for ORs in English and a longer linear distance for SRs in Japanese, in both languages ORs involve a longer structural distance than SRs. Therefore, unlike English, linear and structural distance accounts of processing costs of RCs yield different predictions for Japanese, in that a linear distance account predicts a higher processing cost for SRs while a structural distance account predicts a higher processing cost for ORs. This dissociation between linear and structural distance in Japanese affords the opportunity to investigate which is the more important factor in determining the difficulty of RC comprehension.

(Figure 2 about here)

As discussed above, ORs are typically harder to process than SRs in English, possibly due to either longer linear filler-gap distance, longer structural filler-gap distance, or perhaps
both. Earlier studies on the processing of filler-gap dependencies in RCs and wh-questions (questions involving wh-words such as *what* and *who*) argued that associating a displaced wh-filler with its gap increases working memory load, and that this processing cost is reflected in an ERP component known as the left anterior negativity (LAN) between the filler and the gap. The LAN is a negative voltage deflection that is larger at the front of the head than at the back and is often left-lateralized. It has been observed in both a slow form, with a duration of several seconds, and a phasic form, with a duration of a few hundred milliseconds (e.g., Kluender & Kutas 1993; King & Kutas 1995). For instance, King and Kutas (1995) reported a frontal bilateral slow negative potential in response to ORs in English (6b) when compared to SRs (6a), starting after the relative pronoun and continuing through Regions 1 and 3. In addition, there was a phasic LAN effect immediately following the gap in the OR condition (6b), i.e., at the main verb *admitted* in Region 3.

<table>
<thead>
<tr>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. SR</td>
<td>The reporter [who ___ harshly attacked the senator] admitted the error.</td>
<td></td>
</tr>
<tr>
<td>b. OR</td>
<td>The reporter [who the senator harshly attacked ___] admitted the error.</td>
<td></td>
</tr>
</tbody>
</table>

Other recent studies have reported P600 effects at the gap location instead of or in addition to LAN effects. The P600 is a positive peak at around 600 ms after stimulus onset. For instance, Kaan, Harris, Gibson, and Holcomb (2000) compared embedded yes-no and wh-questions as shown in (7), and found P600 effects at the pre-gap main verb position (*imitated* in this example) in the wh-conditions ((7b) and (7c)).
(7) a. Emily wondered [whether the performer in the concert had imitated a pop star] for the audience’s amusement.

b. Emily wondered [who the performer in the concert had imitated __ ] for the audiences amusement.

c. Emily wondered [which pop star the performer in the concert had imitated __ ] for the audience’s amusement.

Kaan et al. (2000) argued that although the P600 had previously been attributed specifically to syntactic reanalysis (e.g., Osterhout & Holcomb, 1992), their results showed that it can also indicate syntactic integration difficulty in general, such as the relative difficulty of integrating different types of wh-fillers with the rest of the sentence. More recent studies have reported the combination of both LAN and P600 effects in wh-questions in both English (Phillips, Kazanina, & Abada, 2005) and German (Fiebach, Schlesewsky, & Friederici, 2001, 2002).

In English, both wh-questions and RCs involve wh-movement and the filler-gap dependencies that necessarily result. Thus, it is not surprising that the same ERP components have been found to be sensitive to properties of both RCs and wh-questions in English and similar languages. However, in Japanese wh-words typically stay in situ (i.e., they remain in their canonical subject/object position in the sentence), and thus wh-questions are syntactically distinct from RCs. Therefore, the processes underlying the comprehension of these two kinds of structures in Japanese may be less similar than they are in English, and thus perhaps less likely to lead to similar ERP effects. Japanese wh-questions have been investigated using ERPs (e.g., Ueno & Kluender, 2003), but Japanese RCs have not, to the best of our knowledge. However, Japanese RCs have been investigated using reading time measures in a small number of studies (Ishizuka, Nakatani, & Gibson, 2003; Miyamoto & Nakamura, 2003), as have Korean RCs, which have very similar syntactic properties (Kwon, Polinsky, & Kluender, in press, in prep.). These studies have shown that ORs take longer to read than SRs at or starting at the head noun
position. Notice that it is ORs that produce slower reading times, just as in English. Since ORs involve longer structural distances in both languages, while only in English do they also have longer linear distance, these results suggest that structural distance may be the more important kind of distance. Notice also that the difference between Japanese SRs and ORs does not appear until the head noun position at the end of the RC, where it finally becomes clear that the structure is in fact a RC, since it is not until then that it is both clear that there is a RC and what kind of RC it is. This structural ambiguity contrasts with English, where it is clear very early on that there is a RC, and also which kind it is (by whether is it a verb or a noun that follows the relative pronoun, see (1) above), and where differences between SRs and ORs emerge in various processing measures beginning immediately after the relative pronoun.

Given all of the above, we wanted to find out whether the kinds of LAN and/or P600 effects that have been found to be sensitive to filler-gap processing in English would replicate with gap-filler processing in Japanese, and also whether these effects in Japanese would correlate with linear or structural distance. If Japanese gap-filler association is like English filler-gap association, we might expect to see LAN effects between gap and filler, possibly followed by P600 effects when the gap is filled at the filler. However, since the presence of a gap is not clearly indicated until the filler is encountered in Japanese, it is possible that there will not be any differences between SRs and ORs until at or after the head noun position. Additionally, if linear distance is more important, we should see more processing costs indexed by these ERP effects for Japanese SRs in comparison to ORs. On the other hand, if structural distance is more important, as suggested by the reading time studies described above, we would expect to see ERP effects indexing difficulty in ORs.
Experiment 1

Experiment 1 used a self-paced reading task to examine reading times for the experimental stimuli, in order to determine whether our stimuli would show the same pattern of results seen in previous reading time studies, in which ORs took longer to read than SRs.

Method

Participants

Forty native speakers of Japanese (31 females, 9 males; age 18-41 years, mean 26 years) participated in the experiment. They were residents of the San Diego or Urbana-Champaign area and had been outside of Japan for less than 10 years. Participants were reimbursed for their time.

Materials

Stimuli consisted of pairs of sentences with singly-embedded Japanese (a) SRs and (b) ORs, as shown in Table 1. Note that on the surface, the only difference between SR and OR conditions was the case marker of the first noun in the RC (‘senator-ACC’ for SRs and ‘senator-NOM’ for ORs in the example). All the experimental items had the same syntactic structures and the same number of words as the example sentences shown in Table 1.

(Figure 1 about here)

Following Ishizuka et al. (2003), dative-topic-marking was used on the head noun in order to control for potential confounds between RC type and both case-mismatch (Sauerland & Gibson, 1998) and perspective-shift (Sheldon, 1974; MacWhinney, 1982). The case-marking on the head noun indicates its grammatical function in the main clause, rather than its function in the RC. If the head noun is the subject of the main clause, it has a nominative case marker, which is also the case marker it would have in an SR if it were actually present there, since it is also the subject of the RC. In contrast, when a main clause subject noun is modified by an OR,
its case-marking is still nominative, but the case-marking that it would have if it were actually present in the RC would be accusative, since it is the object in the RC. This match or mismatch between the case-marking on the head noun of the RC and its grammatical function within the RC is necessarily confounded with RC type, and has been argued to lead to differences in processing difficulty between the two kinds of RCs (Sauerland & Gibson, 1998). To avoid this potential confound, the head nouns in the experimental items were all given dative-topic marking so that there would be an equivalent discrepancy between the case marking on the head noun and the case marking it would receive if it were actually present within the RC for both SRs (dative-topic/oblique vs nominative/subject) and ORs (dative-topic/oblique vs accusative/object). This approach also controlled for a related potential confound between RC type and degree of perspective shift required between the relative and main clauses, which has also been argued to influence the processing difficulty of RCs (Sheldon, 1974; MacWhinney, 1982). Since the head noun is an oblique instead of the subject in the main clause, there should be a similar degree of perspective shift between the main and relative clauses for both SRs and ORs.

In order to confirm that nouns used at the head noun position (‘reporter’ in the example in Table 1) were equally plausible as both the subject or the object of the RC verb (‘attacked’), 20 native speakers of Japanese (who did not participate in Experiment 1 or Experiment 2) rated simple transitive sentences that were created by replacing the gap in each type of RC with the corresponding head noun, as in ‘The reporter attacked the senator’ vs ‘The senator attacked the reporter’. One hundred pairs of such sentences were constructed and distributed over two lists in a Latin square design and intermixed with 50 filler sentences in a pseudo-random order. Participants rated the sentences on a scale from ‘1’ (strange) to ‘5’ (natural). Twenty pairs of sentences that yielded the largest within-pair differences were discarded. Ratings for the
remaining 80 pairs did not differ significantly [F₁(1,18) = 1.02, p > .1; F₂(1,78) = 2.58, p > .1] when the head noun was used as the subject (mean rating = 4.4) or the object (4.3).

Another norming study was conducted to test whether the verbs used in the RC were strongly transitive-biased. This was done to try to ensure that it would be clear at the RC verb in both SRs and ORs that one of its arguments was missing (i.e., its agent/subject in an SR and its patient/object in an OR). If the RC verbs were not strongly transitive, then the absence of an accusative-marked noun preceding them in ORs could simply mean that the verb was being used intransitively in a mono-clausal sentence or a fact-clause, rather than that an argument was missing. In contrast, in SRs, where there is no nominative-marked noun preceding the RC verb, it is clear that an argument is missing, although there are still multiple possibilities with regard to the structure of the sentence. It could be a mono-clausal sentence with pro-drop, or a fact-clause with pro-drop, or a RC. Thus, the appearance of the RC verb would provide different kinds of information in SRs and ORs, which could lead to processing differences that are not strictly due to RC type. For example, processing might be easier at the RC verb in ORs because it is still possible at that point to interpret the word string as an intransitive construction in a mono-clausal sentence or a fact-clause, while in SRs it becomes clear at the point that an argument is missing. At the next word, the head noun of the RC, relative difficulty could then reverse because the appearance of a noun following an intransitive-bias verb would be the first cue in ORs that there is a RC, while in SRs there was already some indication at the RC verb itself. To try to equate the informativeness of the RC verb about the possible presence of a RC in both SRs and ORs, the bias of the verbs was normed to ensure that only strongly transitive verbs were used, so it would be clear at the verb that an argument was missing in both types of RCs. It is impossible, however, to completely avoid some asymmetry in the cues provided by the RC verb and the head
noun in SRs and ORs, because subjects are much more likely to be dropped than objects (Ueno & Polinsky, submitted). Thus, when a strongly transitive verb appears after only a nominative-marked noun, it may seem stranger than when the same verb appears after just an accusative-marked noun, since subjects are generally dropped more often than objects are. This asymmetry in subject/object pro-drop must be kept in mind when examining the pattern of results in our studies.

Another reason to use only strongly transitive verbs was to avoid another possible reason for ORs to be more difficult than SRs at the head noun. If the verb were intransitive-biased and then it became clear at the head noun that it nonetheless has an object in this sentence, that might lead to greater processing cost that is again not strictly due to RC type.

The 69 different verbs used in the RC of the stimulus sentences were combined with 31 filler verbs that can never take direct objects (e.g., ‘rise’) and given to each participant in a different pseudo-randomized order. Ten native speakers of Japanese, a subset of those who had participated earlier in either Experiment 1 or Experiment 2, did the norming study 0-369 days (mean 146 days) after participating in the original experiment. Participants were presented with the verbs and asked to type the first sensible sentence that came to mind for each verb.\(^5\) Collapsed across participants, 96% of the sentences that were generated with the RC verbs had overt direct objects, confirming that these verbs were highly transitive-biased. Interestingly, only 65% of these sentences had overt subjects (= 35% subject-drop), indicating that subjects can easily be dropped even in the total absence of discourse context.

Eighty pairs of stimulus sentences representing the two experimental conditions were constructed and placed in a Latin square design to create two parallel lists containing 80 experimental items each, such that no one participant saw more than one sentence from any pair,
and every participant saw an equal number of items in each condition. Filler items consisted of 80 sentences of five different types of bi-clausal and mono-clausal constructions (16 sentences per type), including (a) embedded wh-questions, (b) bi-clausal declaratives, (c) ditransitives, (d) transitives in canonical word order, and (e) transitives in scrambled word order. The 80 filler sentences were added to each list, and then sentences in these two lists were pseudo-randomized and divided into 5 blocks of 32 sentences each.

**Procedure**

Participants were seated in front of an IBM compatible laptop computer running the E-Prime software package (Schneider, Eschman, & Zuccolotto, 2002). Participants were timed in a word-by-word self-paced non-cumulative reading task. Stimuli were presented on the computer screen in Japanese characters one bunsetsu at a time. A bunsetsu consists of one free morpheme (lexical word or pronoun) and the bound morpheme/s associated with it (particles modifying the noun/verb), and will be referred to as a “word” hereafter. Each word was presented at the center of the screen and participants pressed the spacebar to reveal each subsequent word of the sentence. Yes/no comprehension questions were presented after each sentence and participants pressed one of two keys on the keyboard to answer them, after which they received feedback. Before beginning the experiment, participants were given a practice set of 20 sentences. The experiment took participants approximately 45 minutes to complete.

**Data Analysis**

Analyses were conducted on both question-response accuracy and reading times per word. Reading times were trimmed so that data points beyond 2 standard deviations from the relevant subject x condition x position cell mean were replaced with the corresponding cutoff value, affecting 5% of the data. The means and analyses presented below are based on the trimmed
reading times. For each sentence position as well as for the post-RC region, a repeated measures analysis of variance was conducted with RC type as a within-group factor, and either subject (with list as a nested factor) (F1) or item (with item group as a nested factor) (F2) as a random factor. An alpha level of .05 was used for all statistical tests, with a p-value of .10 considered marginally significant.

Results

Comprehension Task Accuracy

The mean correct response rate to all the comprehension questions across subjects was 92% (range 81-100%, S.D. 5%). Thus no subject's data were excluded from the reading time analyses based on poor comprehension. The mean correct response percentage did not differ significantly between SRs (91%) and ORs (90%) [Fs < 1].

Reading Times

(Figure 3 about here)

Figure 3 shows the trimmed reading times by sentence position. In the RC region (words 1-3), SRs took longer to read than ORs at the first word position (the subject modifier, ‘new’ in Table 1) [F1(1,38) = 4.74, p < .05; F2(1,78) = 8.10, p < .01], although items were completely identical across conditions at this point (see Discussion). There was no significant difference at the second word position (the RC noun, ‘senator-ACC/NOM’) [F5 < 1]. At word 3 (the RC verb, ‘attacked’), however, SRs took longer than ORs, but this was reliable only in the item analysis [F1(1,38) = 2.27, p > .1; F2(1,78) = 8.25, p < .01].

In the post-RC region (words 4-7), ORs took longer than SRs at the head noun (word 4 ‘reporter-DAT-TOP’) [F1(1,38) = 5.60, p < .05; F2(1,78) = 4.79, p < .05], and also at the following word 5 (‘long-term’), though only marginally so [F1(1,38) = 2.89, p < .1; F2(1,78) = 3.30, p < .1].
There were no significant differences at word 6 (‘colleague-NOM’) \([F_s < 1]\) or word 7 (‘existed’) \([F_1(1,38) = 1.19, \ p > .1; \ F_2(1,78) = 1.01, \ p > .1]\). When reading times for the entire post-RC region (w4-w7) were collapsed together, ORs were read significantly more slowly than SRs \([F_1(1,38) = 8.24, \ p < .01; \ F_2(1,78) = 6.99, \ p < .01]\).

**Discussion**

Slow reading times in the first word position must have been due to noise, given that the word in that position was identical in both conditions. The slowdown did not extend to the following word and so will be ignored in the remainder of the discussion. Spurious effects are sometimes observed on the first word in the sentence in reading time studies because participants get ahead of themselves and unintentionally press the button starting the next sentence when they meant to take a short break between trials. They then take that break, making times at the first word more variable (cf. Miyamoto & Nakamura, 2003).

At word 2, different case markers (nominative in ORs and accusative in SRs) on the noun did not lead to reading time differences, even though it is more typical to start a sentence with a nominative- than accusative-marked noun. However, in the self-paced reading paradigm, effects are often delayed a word, so we could speculate that the accusative-marked noun in SRs caused a slowdown one word later at word 3, although the difference was reliable only by items. A similar trend has been reported in other reading time studies in Japanese and Korean (Miyamoto & Nakamura, 2003; Kwon et al., in press, in prep.), with SRs taking longer to read than ORs within the RC region. Miyamoto and Nakamura reported longer reading times for SRs when all the words within the RC were collapsed together, but they did not provide a plausible explanation for this effect. Kwon et al. reported longer reading times for SRs at the word immediately following the accusative-marked noun position in the RC, which is similar to our
results, though in Kwon et al.’s materials that word was an adverb while in ours it was a verb. Kwon et al. (in prep.) attributed the effect to the possibility that the parser had to look for the missing subject after seeing the accusative-marked noun in SRs, while there was no such need in ORs since they only contained a nominative-marked noun. A similar process might have been taking place in our study as well.

Upon reaching the head noun position, the relative difficulty of ORs and SRs reversed, with ORs taking longer than SRs at both the head noun (word 4) and the following word (word 5), and also when the reading times were combined across the entire post-RC region (words 4-7). Thus there seems to be a reliable processing cost for ORs, starting from the position which clearly indicates that there is a RC, replicating previous studies (Ishizuka et al., 2003; Miyamoto & Nakamura, 2003; Kwon et al., in press, in prep.).

Notice that the reading times on the head noun were the longest in the sentence for both SRs and ORs. One might wonder whether this was due to some lexical property of the head nouns, rather than to RC processing difficulty. The words at this position actually had slightly higher character counts (4.6 on average) than other nouns in the sentence (3.6-3.7 characters on average), probably due to the extra topic-marker in addition to the dative-marker. However, word length could not be the reason for the long reading times, since we also analyzed length-corrected residual reading times (calculated as described in Ferreira and Clifton (1986)) and found that the pattern of results was identical to the one shown in Figure 3. Long reading times on the head noun are also not due to the frequency of the head nouns, since the head nouns were no lower in frequency (mean frequency = 12,848) than the other nouns in the sentence (word 2, mean frequency = 10,510; word 6 = 11,552; F < 1), based on a corpus count of a popular Japanese newspaper (Amano & Kondo, 2000). Nor was it likely to be due to the visual
complexity of the head nouns, since the character counts of Chinese characters, which tend to be more visually complex than syllabic characters, were not significantly higher for the head nouns (mean Chinese character count = 1.96) than for the other nouns in the sentence (word 2 in RC = 1.89; word 6 in main clause = 1.83; F < 1).

Therefore, the long reading times at the head noun position seem most likely to be due to the difficulty of processing the RC structure for both SRs and ORs. This is the point in the sentence where the parser should be constructing the RC structure and filling the gap with the head noun for both SRs and ORs, and the reading times show that that is harder in ORs. This provides additional support for the structural distance account of the RC difficulty, since it is ORs that have greater structural distance in Japanese, just as in English.

Experiment 2

Experiment 2 investigated ERPs in response to Japanese SRs and ORs. To recap, our major questions were (a) whether there would be LAN and/or P600 effects in Japanese RCs like those observed previously for English RCs and wh-questions (Kluender & Kutas, 1993; King & Kutas, 1995; Kaan et al., 2000; Phillips et al., 2005) and (b) whether ERP results would lead to a similar conclusion as the reading time results showing that Japanese ORs are more difficult, and thus provide additional support for the structural distance account of the difference.

Methods

Participants

Thirty-three native speakers of Japanese (23 females, 10 males; age 20-34 years, mean 26 years) who did not participate in Experiment 1 were included in the study. Participants were right-handed and had normal or corrected-to-normal vision. They were residents of the Urbana-
Champaign area and had been outside of Japan for less than 10 years. Participants were reimbursed for their time.

*Materials*

The stimuli and design were identical to Experiment 1.

*Procedure*

Participants were seated facing a computer monitor in a sound-attenuated room. Stimuli were presented on the center of a computer screen in Japanese characters one word (or *bunsetsu*) at a time with 450 ms duration and 650 ms stimulus onset asynchrony. Yes/no comprehension questions were presented after each sentence and participants responded using the mouse, after which they received feedback. Before beginning the experiment, participants were given a practice set of 20 sentences. Participants were given as much rest as they wished between blocks of sentences. The experiment took participants approximately 2.5 hours.

*Electrophysiological Recording*

The electroencephalogram (EEG) was recorded from 25 positions, using Ag/AgCl electrodes attached to an elastic cap (Easy-Cap). Electrodes were positioned on the two mastoid processes, and data were collected using the left mastoid as the reference. The EEG was later algebraically re-referenced to the mean of the activity at these two mastoid electrodes. To detect blinks and lateral eye-movements for later correction, additional electrodes were placed beneath the right eye and at the outer canthi of both eyes. Impedances were kept below 10KΩ. The EEG was amplified with a bandpass of 0.01 to 30 Hz, digitized at 200 Hz, and stored for off-line analysis. Data with excessive blinks were corrected using an eye movement correction procedure (Gratton, Coles, & Donchin, 1983).
Data Analysis

Analyses were conducted on question-response accuracy and ERP waveforms. ERP measurements were examined for two-word averages to reveal phasic effects, and four-word averages for longer-lasting effects. The analysis epochs in the two-word averages were 1750 ms long, including a 100 ms prestimulus baseline, while four-word averages were 3050 ms long, again including a 100 ms prestimulus baseline.

The statistical analyses were done separately on midline (Fz, Cz, and Pz), parasagittal (AF3/4, F3/4, FC3/4, C3/4, CP3/4, P3/4, PO7/8), and temporal (F7/8, FT7/8, T3/4, T5/6) electrodes, as well as on individual electrodes. Midline analyses consisted of repeated measures ANOVAs with two within-group factors, including two levels of RC type and three levels of anterior/posterior sites, and subject (with list as a nested factor) as a random factor. Parasagittal analyses consisted of repeated measures ANOVAs with three within-group factors, including two levels of RC type, seven levels of anterior/posterior sites, and two levels of hemisphere. Temporal analyses consisted of repeated measures ANOVAs with three within-group factors, including two levels of RC type, four levels of anterior/posterior sites, and two levels of hemisphere. An alpha level of .05 was used for all statistical tests, with a p-value of .10 considered marginally significant. The Huynh-Feldt correction for lack of sphericity was applied whenever applicable (Huynh & Feldt, 1976). Original degrees of freedom are reported with the corrected probability level.

Results

Comprehension Task Accuracy

The mean correct response rate to all the comprehension questions across subjects was 91% (range 84-98%, S.D. 4%). Thus no subject's data were excluded from the ERP analyses.
based on poor comprehension. The mean correct response percentage did not differ significantly between SRs (89%) and ORs (87%) \( F_1(1,31) = 1.60, p > .1; F_2(1,78) = 1.02, p > .1 \).

**ERPs**

Six percent of the data were rejected due to eye movement and other artifacts. Sentences were compared in the RC region (RC + head noun, ‘new senator-ACC/NOM attacked reporter-DAT-TOP’ in Table 1), to examine how gap-filler dependencies in Japanese RCs were processed, and also at the post-RC region (head noun + remainder of the sentence, ‘reporter-DAT-TOP long-term colleague-NOM existed’), to determine whether there were any effects of RC type after the gap was filled by the head noun.

**Relative clause (RC) region.** Visual inspection of the RC region showed bilateral anterior negativity at the RC verb and head noun position (‘attacked reporter-DAT-TOP’ in Table 1) of ORs (see Figure 4). To quantify this observation, ANOVAs were performed in the latency window of 300 to 1250 ms poststimulus onset of ‘attacked’, covering the 300-600 ms (standard latency for LAN) windows of both ‘attacked’ and ‘reporter-DAT-TOP’. A significant or marginal main effect of RC type was found in both the midline \( F(1, 31) = 7.36, p < .05 \) and parasagittal \( F(1, 31) = 3.04, p < .1 \) arrays. In addition, there was a marginal interaction between RC type and anteriority in the midline array \( F(2, 30) = 3.04, p < .1 \). ANOVAs run on individual electrodes in the same latency window revealed a significant main effect of RC type at Fz, AF3, F4, FC4, and C4, as well as a marginal main effect at Cz, F3, and C3. These effects indicated that ORs were more negative than SRs, especially at frontal regions.

(Figure 4 about here)

**Post-relative clause (RC) region.** Figure 5 shows the comparison between RC type at the post-RC region, from the head noun position to the sentence end (‘reporter-DAT-TOP long-term
colleague-NOM existed’ in Table 1). Visual inspection of these four-word averages showed a slow continuous divergence between SRs and ORs, in which ORs were more positive than SRs, starting at about 500 ms after the onset of ‘reporter-DAT-TOP’ and continuing throughout the epoch to the sentence end. To capture this observation, ANOVAs were performed in the latency window of 500 ms to 2950 ms poststimulus onset of ‘reporter-DAT-TOP’. There was a significant or marginal main effect of RC type in all three arrays [midline: F(1, 31) = 7.77, p < .01; parasagittal: F(1, 31) = 4.82, p < .05; temporal: F(1, 31) = 3.36, p < .1], as well as a significant RC type x anteriority interaction in the temporal array [F(3, 29) = 3.38, p < .05]. ANOVAs run on individual electrodes in the same latency window revealed a significant main effect of RC type at Fz, AF4, T4, C4, T5, T6, CP3, P3, and P4, as well as a marginal main effect at Cz, C3, PO7, and PO8. These effects indicated that ORs were more positive than SRs, especially at centro-posterior regions.

(Figure 5 about here)

Discussion

To summarize, ORs elicited greater bilateral anterior negativity than SRs at the RC verb and head noun positions in the RC region (Figure 4). In the post-RC region starting from the head noun and continuing to the end of sentence, ORs elicited greater centro-posterior positivity than SRs (Figure 5). The anterior effect in the RC region has the typical latency and anterior scalp distribution for the LAN, but it is bilaterally distributed rather than lateralized. Although anterior negativities have been found to be left-lateralized to varying degrees in several studies (hence the usual name LAN), there have also been previous observations of bilaterally distributed and even right-predominant versions of anterior negativities (e.g., Müller, King, & Kutas, 1997; Ueno & Kluender, 2003). The functional and neurophysiological significance of
different scalp distributions for anterior negativities during sentence processing remain to be
determined. We assume here that both bilaterally distributed and lateralized versions signal
similar kinds of processing difficulty, though differences in the nature and/or degree of difficulty
may contribute to differences in scalp distribution. The centro-posterior effect in the post-RC
region is harder to clearly identify as one of the ERP components previously observed in
sentence processing studies. In what follows, we will discuss each of these effects in turn.

Relative Clause (RC) Region

One possible interpretation of the anterior negativity observed in the RC region (as
schematized in (8)) is that it reflects demands placed on working memory by both the storage of
a gap and its subsequent retrieval for gap-filling (cf. Kluender & Kutas, 1993). On this
interpretation, the parser recognizes the gap in ORs upon seeing a transitive-biased verb
(‘attacked’ in (8b)) immediately following a nominative-marked noun, since there is no object in
the usual position. This leads to processes that tax working memory until the object-gap in the
RC is filled by the head noun. The parser would also recognize a gap in SRs either immediately
at the accusative-marked noun or one word later at the RC verb (since at the accusative-marked
noun itself, it is possible that the subject noun has been dropped, or that the accusative-marked
noun is scrambled out of the default subject-object order), but this seems to be easier, as
indicated by the ERP results.

(8) a. SR [___ new senator-ACC attacked] reporter-DAT-TOP ...

          ←AN→

b. OR [new senator-NOM ___ attacked] reporter-DAT-TOP ...

As pointed out earlier, another possible explanation has to do with differences in the
likelihood of subject- and object-drop in Japanese. It is much more common to drop subjects
than objects with transitive-biased verbs like those used in this experiment, as shown in our
norming test. If the sentence is parsed as a simple mono-clausal sentence (or a fact-clause with
*pro*-drop like (5a) or (5b)) up until the head noun, at the RC verb the ORs appear to be missing
an object, while SRs appear to be missing a subject. Since missing objects are less common, the
appearance of a missing object in the ORs may contribute to a greater processing cost. In
addition to reflecting increased working-memory load for the processing of structures involving
filler-gap dependencies, anterior negativities have also been linked to syntactic processing
difficulty in general, such as that triggered by violations of phrase structure (e.g., Neville, Nicol,
Barss, Forster, & Garrett, 1991) or morphosyntactic constraints (e.g., Coulson, King, & Kutas,
1998), by non-preferred disambiguations of temporally ambiguous sentences (Kaan & Swaab,
2003), and by case-marked determiners (in German) that indicate that argument nouns are not in
their canonical order (Rösler, Pechmann, Streb, Röder, & Hennighausen, 1998)⁹. Thus it would
be possible to link the anterior negativity found in the present study to the processing of a
syntactically atypical construction with object-drop. Participants might have (incorrectly)
recognized and reacted to such a construction at the RC verb position, and the effect might have
carried over to the following head noun position.

*Post-Relative Clause (RC) Region*

The slowly developing divergence between SRs and ORs across this sentence region has
a scalp distribution like that of P600, but a timecourse that is not at all like the usual P600
timecourse. Thus, it is not clear whether or not this effect is related to previously observed P600
effects, or to an entirely different phenomenon. Given that, it is not even clear whether to take
the perspective that ORs produce more centro-posterior positivity or that SRs produce more
centro-posterior negativity. However, since previous observations of ERP effects related to
sentence-processing difficulty due to factors other than word meaning have all found greater
difficulty to be associated with anterior negativity and/or posterior positivity, it seems to make
more sense to describe the posteriorly distributed effect\(^\text{10}\) observed here as greater positivity in
ORs. In addition, the fact that reading times on the RC head noun were longer for ORs than for
SRs in Experiment 1 suggests that it is ORs that are more difficult, providing support for the idea
that it makes more sense to describe the ERP effect as greater positivity for ORs. However,
before further interpreting the results from that perspective, it is important to rule out a couple of
other alternatives.

A somewhat remote possibility is that the effect observed here is related to N400 effects,
in which words whose meanings are harder to integrate with their contexts lead to greater centro-
posterior negativity. Such effects have been reported at the end of sentences containing syntactic
and/or semantic anomalies that evoke P600 and/or N400 effects earlier in the sentence
(Osterhout & Holcomb, 1992; Hagoort, Brown, & Groothusen, 1993; Osterhout & Nicol, 1999),
and have been interpreted as showing that the kinds of processing problems that initially evoke
N400/P600 effects also make it difficult to integrate the meanings of subsequent words. If that
were the source of the effect found here, it would be more appropriate to describe it as greater
negativity for SRs. However, unlike these studies, our effect started at the fourth word from the
end of grammatical, rather than ungrammatical, sentences, and it was not preceded by
P600/N400 effects earlier in the sentence. Thus, it seems unlikely that the posteriorly distributed
effect observed here is related to these N400-like “sentence-end wrap-up” effects.

Another possibility concerns artifacts that can be introduced by the waveform baselining
process. The larger anterior negativity elicited during ORs started at the RC verb and extended
over the head noun following it. Re-baselining the 4-word waveforms starting at the head noun

thus could artifactually introduce a later difference in the opposite direction. That is, if the
greater anterior negativity elicited by ORs slowly returned to a more positive default state over
the words following the head noun, forcing the waveforms together at the start of the head noun,
as the baselining procedure does, would make it appear that the waveforms gradually diverged in
the opposite direction from their earlier divergence, when in fact they were just continuing to
converge from that earlier divergence. However, if that were the source of the gradually
increasing positivity observed in OR sentences baselined at the head noun, its scalp distribution
should be the same as that for the negativity observed earlier in the sentence, i.e., larger
differences at the front of the head than at the back. Since the scalp distribution of the difference
observed here starting at the head nouns was larger over the back of the head than the front, it
cannot be explained in this way\textsuperscript{11}. Therefore, we now return to an interpretation of the
differences as greater positivity in response to ORs and continue our discussion.

The difference has a reasonable scalp distribution for a P600 effect, yet is in the form of a
steady long-lasting shift instead of a local peak. However, LAN effects have been reported in
both phasic and long-lasting versions (e.g., Kluender & Kutas, 1993; King & Kutas, 2005;
Fiebach et al., 2001, 2002), so perhaps the same variations are possible for P600 effects. In fact,
Van Petten and Kutas (1991) reported a slow positive shift in response to syntactically
incoherent sentences, such as \textit{Be place prefer the was city it and sure be perfume}, and more
recently, Casado, Martín-Loeches, Muñoz, & Fernández-Frías (2005) reported a long-lasting
positive shift for a phrase structure reallocation process in Spanish. These effects are argued to
index syntactic processes typically related to the P600, and the positivity effect in our experiment
may be a similar variant.
The continuous positivity starting at the head noun is more clearly due specifically to RC processing than is the anterior negativity evoked by earlier words, since there is no longer any ambiguity about whether the sentence fragment so far is a part of a mono-clausal sentence or a fact-clause, or instead contains a RC. Consistent with previous results obtained by Kaan et al. (2000), this positivity seems to index the greater syntactic integration costs of filling object-gaps. This fits well with the structural distance account of differences in difficulty between SRs and ORs, in that the object gap position is more deeply embedded and thus more structurally distant from the head noun, leading to more retrieval and integration costs.

However, one may wonder why the effect was long-lasting rather than phasic. As shown in the reading times, the head noun position for both SRs and ORs seems to require substantial processing resources, since it had the longest reading times in the sentence. This is the position in the sentence where it becomes clear that there is a RC, so if participants have not begun to do so earlier, this is where they have to recognize and construct a RC structure. It may have been especially difficult to simultaneously do both that and search farther down the phrase structure for the gap for ORs, which may have led to a sustained positivity. A possibly related finding in Kluender and Kutas (1993) was that LAN effects were observed across several words after a gap had been filled, suggesting that gap-filling is a resource-demanding process whose effects continue to be felt for some time over subsequent words.

Another possibility is that the sustained positivity reflects reanalysis costs, as the P600 has been argued to do (e.g., Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994). However, that is unlikely to be the case here. First, because the verbs used in the RC were highly transitive-biased, it is unlikely that participants expected OR sentences to continue as an intransitive construction and then had to revise that analysis at the head noun position.
Second, as discussed above, subject-drop is much more common than object-drop in Japanese. Thus SRs involving missing subjects should have been more likely to make participants think that the sentence would continue as a mono-clausal sentence (or perhaps a fact-clause) than ORs with missing objects, and this should have resulted in a higher reanalysis cost at the head noun position in SRs rather than in ORs.

**General Discussion**

\[ OR > SR \]

The two experiments reported here both suggest that Japanese ORs are harder to process than SRs. However, there were some discrepancies between them. In particular, in the RC region the effects appear to go in opposite directions for reading times and ERPs. At the RC verb, there was a trend in Experiment 1 for slower reading times in SRs than in ORs, suggesting that SRs had a higher processing load at that point. In contrast, at that same position in Experiment 2, there was more anterior negativity elicited by the RC verb in ORs than in SRs, suggesting a higher processing load for the ORs at that point.

We speculated in the discussion of Experiment 1 that one factor contributing to longer reading times for the RC verb in SRs may have been the atypicality of a sentence beginning with an accusative-marked noun, as the SRs did. Since effects in self-paced reading times are sometimes delayed a word, perhaps reading times were longer at the verb because of spillover from the previous accusative-marked noun, due to its atypicality as the first noun in the sentence. There is no reason to expect effects to be similarly delayed a word in the ERPs, so it would be possible to get different patterns of results at the RC verb in the two kinds of measures. However, although this account suggests that there should have been some kind of difference in the ERP waveforms evoked by the accusative- vs nominative-marked nouns themselves, there
was no such difference. Instead, the earliest difference between conditions in the ERP waveforms was an anterior negativity to the RC verb in ORs, which continued over the following head noun. In the discussion of Experiment 2, we suggested that this may have been due either to the greater difficulty of processing of the gap-filler dependency in ORs, or to the non-canonicity of object-drop if a mono-clausal or fact-clausal interpretation was being constructed. The discrepancy between reading times and ERPs might have occurred because multiple different kinds of processes were taking place at the RC region, as the parser had to entertain multiple possibilities because of the degree of temporary ambiguity at that point in the sentences. Thus it is possible that the two methodologies are sensitive to different aspects of the processing that was taking place at that point.

Starting at the head noun position, which clearly indicates the RC structure, both reading times and ERPs showed extra processing costs for ORs that continued to the end of the sentence. In addition, although the difference was never statistically significant, mean accuracy on comprehension questions was also slightly lower for ORs than for SRs in both the reading time study (SR: 91% vs OR: 90%) and the ERP study (SR: 89% vs OR: 87%)\textsuperscript{13}, suggesting extra processing costs for ORs.

*What Kind of ERP?—Linear vs Structural Distance*

Our reading time experiment replicated the results of previous studies finding that ORs took longer to read than SRs starting at the head noun position. Our ERP experiment showed further that similar ERP components are elicited by English and Japanese ORs: anterior negativity is observed between filler and gap or gap and filler, and posterior positivity is observed when the gap is filled, although the posterior positivity is phasic for English and long-lasting for Japanese. If we interpret the anterior negativity effect in the RC region as associated
with gap-filler dependencies, we could further say that the pattern of results involving anterior
negativity and posterior positivity suggests similar parsing operations for both filler-gap
dependencies in English and gap-filler dependencies in Japanese. However, in the discussion
of Experiment 2 we raised a possible alternative interpretation of the anterior negativity that is
not specifically about RC processing, i.e., that ORs initially appear to be missing an object,
which is more unusual than a missing subject in Japanese sentences. Therefore, what we can say
with more certainty is that gap-filler association in Japanese RCs seems to involve a long-lasting
integration process after the filler, as indexed by the continuous posterior positivity in ORs. If
we assume that the continuous positivity indicates greater syntactic integration cost for ORs,
both ERP and reading time data are more consistent with a structural rather than linear distance
account of RC processing difficulty in Japanese.

An Alternative Interpretation

We have been focusing on the linear vs structural distance accounts, but we are aware
that this is not the only possible interpretation. It could be that the discourse prominence of
subjects over objects causes the extra processing cost to ORs. Some linguists have proposed that
Japanese RCs do not involve syntactic movement and that gaps are actually pros (null argument
pronouns) instead of traces left by syntactic movement (e.g., Comrie & Horie, 1995; Matsumoto,
1989; Murasugi, 2000). On this interpretation, the gap in the RC is identified in the same way as
a pronoun, either by an entity in a given discourse or by a cataphoric (forward reference,
backwards anaphora) link with the head noun in the absence of plausible discourse referents.
Since there was no discourse context in the present study, gaps in our stimuli would have been
identified in the latter manner. Then rather than gap-filler distance (either linear or structural),
what would actually matter is that the subject *pro* is easier to link cataphorically with the head noun than the object *pro* is, possibly due to its discourse prominence.

There has been much work showing that antecedents in the subject position are easier to access than antecedents in the object position in anaphor resolution (e.g., Frederiksen, 1981; Crawley, Stevenson, & Kleinman, 1990), suggesting that subjects are more prominent than objects for pronoun reference. To the best of our knowledge, there has not been much work from the opposite perspective about whether cataphoric/anaphoric pronouns in the subject position are easier to identify than those in the object position. However, one recent reading time study in Korean (Kwon et al., in press, in prep.) has reported a higher processing cost when object *pros* are cataphorically referenced than when subject *pros* are, indicating that subject/object asymmetry coming from a pronoun instead of its antecedent may also influence processing difficulty.

Possibly related to this line of interpretation, several ERP studies (e.g., Cowles, Kutas, & Kluender, 2003; Van Berkum, Brown, Hagoort, & Zwitserlood, 2003) have reported anterior negativity and/or P600 effects in the establishment of anaphoric links. Cowles et al., in particular, reported a sustained anterior negativity when the parser is carrying referential ambiguity, as well as a P600 effect when that referential gap was filled. Thus the present results could be linked with this type of interpretation, and we hope to move the discussion forward by exploring more types of filler-gap/gap-filler dependencies in our future research.

Conclusions

To conclude, our experiments have shown that Japanese ORs are harder to process than SRs, revealing higher processing costs from the head noun to the sentence end for ORs than SRs in both reading times and ERPs. Our data also suggest that gap-filler association in Japanese
ERPs to Japanese Relative Clauses  35

RCs involve a long-lasting integration process after the filler, as indexed by a continuous centro-posterior positivity in ORs. Finally, both ERP and reading time data seem more consistent with a structural distance account than a linear distance account for Japanese RCs.
References


are revealed by event-related brain potentials. *Journal of Memory and Language, 38*, 150-176.


Appendix

Materials

Experimental Conditions:

a. Subject Relative (SR)

新任の議員を非難した/記者には長年の相棒がいた。

b. Object Relative (OR)

新任の議員を非難した/記者には長年の相棒がいた。

Only the SR versions are given below, since the only difference between them and the OR versions is the case-marking particle on the first noun, as highlighted in the examples above.

1a. 新任の議員を非難した/記者には長年の相棒がいた。
2a. 真面目な父を誤った/兄にはまともな友達が少なかった。
3a. 評判の先輩を拓いた/選手には練習熱心ながんばり屋が多かった。
4a. 人気者の先生を誤った/生徒たちには根暗な人が多かった。
5a. 高名な人物を批判した/人々には派手な中年女性が多かった。
6a. 風呂な父を支えた/母には熱烈な信奉者が多かった。
7a. 頑固な社長を真実に見た/部下には優秀な企業戦士が多かった。
8a. 年寄りの母を褒め称えた/看護士には臨機応変な者が多かった。
9a. 中年の女性社員を助けた/同僚には誠実な人物が多かった。
10a. 頭脳明晰ないとこを/iらずやんだ/学生には青白い優等生が多かった。
11a. 保守派の教頭先生を評判がした/母親達には高学歴のインタリが多かった。
12a. 岐阜面な書記を助めた/委員長には高校生の娘がいた。
13a. 冷血漢のスパイを調査した/組織には優秀な手下が多かった。
14a. 照れ屋な寮母さんを助けた/女子学生には同郷の友人が少なかった。
15a. お天気屋の社長を追い出した/株主にはうんざり仲間がついていた。
16a. 聡明な国王が骗した/貴族にはずるい悪党がついていた。
17a. わがままなちびっこを叩いた/母親さんには適齢期の長女がいた。
18a. タバコ屋の亡くなった/紳士にはたくさんの人々がいた。
19a. 賢明な店長を信頼した/コックにはたくさんの人々がいた。
20a. 排他的な政治家を排除した/運動会には熱狂的な支持者がいた。
21a. 屈託ない跡継ぎを鮮明に見限った/父親には年若い愛人がいた。
22a. 取引先の御曹司を初めれた/令嬢には双子の妹がいた。
23a. 近所の囲碁仲間に愛した/曾祖父には長生きな連れ合いがいた。
24a. 古株の会員を排除した/委員長には若い傍観者がいた。
25a. 隣人の首を追い返した/男には意中の女性がいた。
26a. アルバイトの若者を指導した/婦人には手強い敵がいた。
27a. 陽気な娘をうるさがった/曾祖父にはヘタレの家政婦さんがついていた。
28a. 石頭の上司を嫉妬がた/刑事には入院中の相棒がいた。
29a. 偉大な指導者を接待した/貴婦人には年若い恋人がいた。
30a. 泣き上戸の常連客を呼び止めた/ママには出っ歯の用心棒がついていた。
31a. 汚い浮浪者を殴り倒した/不良にははっさなガールフレンドがいた。
32a. お屋敷の坊ちゃんを敬愛した/婆やには愛らしい孫娘がいた。
男勝りな太っ腹な手強いおませな元気な新人のしぶとい無口な男勝りな同室の直属の野暮ったい皮肉な中堅どころの野暮な夜勤明けの暴れん坊の内気な非情なしっかり者の新人類のせこい有名な怒りっぽいずうずうしい雅やかな赤毛の高徳の野党の名家の小太りの女たらしの苛めっ子を杀したはげました招待したウグイス嬢を選手を大家を助けたのがののしった殴った挑発した避けたののしったひやかした兵士にはからかった無視した選んだどなった指揮者には誹告したののしった叱った呼び止めたひやかした上司には手なずけた盗賊には秘書には神父には教師には兵士には姑には小姑がいた有能な強力な監督には有能な指導者があった。
Footnotes

1 More strictly speaking, Gibson (1998, 2000) concerns the number of new discourse referents between a filler and its gap. When a noun between a filler and its gap is reduced to a pronoun, processing difficulty is said to be reduced (cf. Gordon, Hendrick, & Johnson, 2001; Warren & Gibson, 2002).

2 Also see Hawkins (1994) for an account based on the combination of linear and structural distance.

3 Whether the head noun is considered to originate outside (e.g., Han & Kim, 2004) or inside (e.g., Fukui & Takano, 2000) the RC is controversial, but none of our arguments or conclusions depend on which of these is the better analysis.

4 More recently, Ishizuka, Nakatani, and Gibson (2006) reported the opposite effect when Japanese SRs and ORs were presented in a discourse context. See footnote 15 in General Discussion.

5 The sentences produced by participants in the norming study did not resemble the stimulus sentences in general. Participants did not use the same agent or patient (or a reversed agent or patient) that were used in the stimulus sentence with the corresponding verb, except in six sentences out of the 690 sentences examined (0.9%).

6 We only included the frequency counts for nouns (without any case-marking particles) whose exact orthography (i.e., the particular combination of Chinese characters (kanji) and syllabic characters (kana)) was in the entry of Amano and Kondo (2000). This resulted in 70 data points for the nouns in the RC at sentence position 2, 68 data points for the head nouns at sentence position 4, and 70 data points for the main clause nouns at sentence position 6.
The total number of participants actually run was 51. However, due to a hardware problem, data from the first 19 participants had to be discarded. Four other participants had additional recording problems with too much noise or drift, and their data were also discarded. In addition, another participant’s data were accidentally deleted. Six participants from the 19 participants affected by the hardware problem came back for a second session 52-139 days (mean 113 days) after their original session. Exclusion of these six participants does not alter the patterns in the data but weakens the statistical power.

The presentation rate of 650 ms per word is longer than the 500 ms per word used in many English studies, but was deemed optimal after consulting five native speakers of Japanese. Given both the visual complexity of Chinese characters often used in Japanese and the fact that many of the Japanese bunsetsu translate as multiple English words, it is not surprising that readers needed more time per bunsetsu.

To what extent all of these processes involve working-memory load is controversial (cf. Kluender & Kutas, 1993; Coulson et al., 1998).

There are two frontal electrodes that showed a significant difference between SRs and ORs, namely, Fz and AF4. However, recall that there was anterior negativity in response to ORs at the relative clause verb (in addition to the head noun) in the relative clause region. This negativity can push ORs down further than actual when waveforms are re-baselined as discussed in the present section. This could be obscuring the comparison for these electrodes.

Perhaps except for the few frontal electrodes discussed in footnote 10 above.

Such a difference might be predicted to take either the form of an anterior negativity or a posterior positivity or both. In German, where case-marking particles precede nouns, Rösler et al. (1998) found anterior negativities in response to case-marked determiners that indicated that
phrases were not in canonical order, but posterior positivities to the nouns that followed those
determiners. Since in Japanese the case-marking particle was presented together with its noun,
either effect or a combination of both might have been expected.

13 The reason why mean accuracy for the ERP experiment was 2-3% lower overall than
that for the reading time experiment may be because participants could not control the
presentation rate of the sentences in the ERP study. They may have needed more time to read
some parts of the sentences.

14 If we classify both English wh-questions and relative clauses together as "filler-gap
dependencies", we can easily link both our anterior negativity and centro-posterior positivity
effects to the processes of filler-gap/gap-filler associations in both English and Japanese.
However, if we focus only on the processing of relative clauses in English, neither of the two
ERP studies on English SRs vs ORs that we know of reported any posterior positivity effects in
response to ORs. However, this may be at least partly because these earlier studies paid little
attention to P600 effects. Single word averages of King and Kutas (1995: 383) seem to show a
small posterior positivity effect at the RC verb (the pre-gap position similar to Kaan at al.
(2000)) of ORs. King and Kutas only examined the 300-500 ms time window and reported a RC
type x electrode interaction at this position (p. 385), but the interaction could in part have been
due to a posterior positivity effect, in addition to the LAN they reported. Müller et al. (1997)
conducted an auditory version of King and Kutas, but did not seem to reveal any posterior
positivity effect around the gap of ORs. This may have something to do with the auditory
presentation of their stimuli.

15 Recently, Ishizuka et al. (2006) investigated the processing of Japanese SRs and ORs
in a discourse context. They compared SRs and ORs in the following discourse context and
reported that SRs took longer to read than ORs at the RC verb (‘interviewed’ in the example),
while there was no difference at the head noun and later positions.

ある番組でレポーターが作家をインタビューした。/
一方その作家は次の作品の材料に別のレポーターをインタビューした。/
A reporter interviewed a writer on a TV program. /
Then the writer interviewed another reporter for his new novel./

Taro: /
選挙に立候補したのはどちらのレポーター
‘Which reporter stands as a candidate for the election?’

Hanako: /
SR: 作家をインタビューしたレポーターだったらしいよ
writer-ACC / interviewed / reporter / was / it seems
‘It seems to be the reporter who interviewed the writer’

OR: 作家がインタビューしたレポーターだったらしいよ
writer-NOM / interviewed / reporter / was / it seems
‘It seems to be the reporter who the writer interviewed’

Ishizuka et al.’s (2006) data can be interpreted according to the alternative analysis of
Japanese RCs discussed in this section. It is possible to argue that the gap was filled by (or the
pro was coreferenced with) the corresponding referent in the discourse before the head noun
position. This may be why there was no reading time difference at the head noun position in
their data, unlike other reading time studies.

Ishizuka et al. (2006) argue that their data support the linear distance account over the
structural distance account. They argue that the longer reading times for ORs in previous studies
were due to greater temporary ambiguity of ORs, which are more likely to be interpreted as
mono-clausal with sentence-initial nominative-marked nouns than are SRs with sentence-initial
accusative-marked nouns. They argue further that SRs actually take longer to read than ORs
when participants are led to expect a RC construction by the discourse context. However, the
prevalence of subject-drop in the sentences produced in our norming study suggests that even
when there is no discourse context, participants could imagine a mono-clausal sentence with a missing subject upon seeing an accusative-marked noun in SRs. Thus ORs do not necessarily have to be more temporarily ambiguous than SRs. Then the longer reading times for SRs at the RC verb may have been either because the accusative-marked noun caused a slowdown one word later, just as we observed in Experiment 1, or because the part of the discourse related to the answer to the SR question than the OR question was mentioned earlier (i.e., the event of a reporter interviewing a writer was mentioned before the event of the writer interviewing another reporter in the given discourse), and thus may have taken longer to access.
Table 1

*Stimuli*

a. Subject Relatives (SRs)

\[
\text{新任の議員を非難した記者には長年の相棒がいた。}
\]
\[
\text{[new senator-ACC attacked] reporter-DAT-TOP long-term colleague-NOM existed}
\]

‘(For the reporter [(who) attacked the new senator], a long-term colleague existed →)
The reporter [(who) attacked the new senator] had a long-term colleague.’

b. Object Relatives (ORs)

\[
\text{新任の議員が非難した記者には長年の相棒がいた。}
\]
\[
\text{[new senator- NOM attacked] reporter-DAT-TOP long-term colleague-NOM existed}
\]

‘The reporter [(who) the new senator attacked] had a long-term colleague.’
Figure Captions

*Figure 1.* Syntactic structures for subject relatives (SRs) and object relatives (ORs) in English.

*Figure 2.* Syntactic structures for subject relatives (SRs) and object relatives (ORs) in Japanese.

*Figure 3.* Mean trimmed reading times for each sentence position for subject relatives (SRs) and object relatives (ORs).

*Figure 4.* ERPs from frontal (AF3/4, F3/4, FC3/4, Fz) electrodes at the relative clause verb and head noun positions of SRs vs ORs. Negativity is plotted up.

*Figure 5.* ERPs from all electrodes at the post-relative clause region (from the head noun to the sentence-end) of SRs vs ORs. Negativity is plotted up.
Figure 1
Figure 2
Figure 3

[新任の議員を/が非難した]記者には長年の相棒がいた。
Subject Relatives (SRs)

[新任の議員を非難した] 記者には長年の相棒がいた。

Object Relatives (ORs)

[新任の議員が非難した] 記者には長年の相棒がいた。
Subject Relatives (SRs)


Object Relatives (ORs)

[new senator-NOM attacked] reporter-DAT-TOP long-term colleague-NOM existed