

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

Mieko Ueno

Department of Linguistics, University of Oregon

Susan M. Garnsey

Department of Psychology, University of Illinois, Urbana-Champaign

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Address correspondence to:

Mieko Ueno
Department of Linguistics
1290 University of Oregon
Eugene, OR 97403-1290

phone: (217) 721-8227
fax: (541) 346-5961
email: miueno@uoregon.edu

Abstract

Using reading times and event-related brain potentials (ERPs), we investigated the processing of Japanese subject and object relative clauses (SRs/ORs). Previous research on English relative clauses shows that ORs take longer to read (King & Just, 1991) and elicit anterior negativity between fillers and gaps (King & Kutas, 1995), which is attributed to increased working memory load due to longer filler-gap distance. In contrast to English, gaps in Japanese relative clauses are less clearly marked and precede their fillers, and the linear gap-filler distance is shorter in ORs than in SRs. Nevertheless, Japanese ORs take longer to read (Ishizuka, Nakatani, & Gibson, 2003; Miyamoto & Nakamura, 2003), perhaps because in both English and Japanese, gaps in ORs are more deeply embedded, with the result that there is longer structural distance between filler and gap 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 for ORs than SRs in both reading times and ERPs, and thus are most consistent with a structural distance account. The results also showed that gap-filling difficulty manifests itself as larger centro-posterior positivity in ERP responses to Japanese OR sentences, just as it does in English long-distance dependencies (cf. Kaan, Harris, Gibson, & Holcomb, 2000; Phillips, Kazanina, & Abada, 2005; Gouvea, Phillips, Kazanina, & Poeppel, submitted). There is also evidence that there is a probabilistic cue of a gap in Japanese OR sentences that triggers anterior negativity—similar to the triggering of anterior negativity by a clearly marked filler in English filler-gap sentences (cf. Kluender & Kutas, 1993a, b). Thus, we argue that there is substantial similarity between the processing of English filler-gap constructions and Japanese gap-filler constructions.

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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 self-paced reading times and ERPs, and compares the results to similar studies done in English and other languages.

English and Japanese Relative Clauses (RCs)

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	←relative clause (RC)→
↓	
<i>the reporter</i>	<i>[who __ attacked the senator]</i>
	FILLER GAP

b. Object relative (OR)

<i>the reporter</i>	<i>[who the senator attacked __]</i>
	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 difference between processing SRs and ORs is often tied to the notion of filler-gap dependencies. In (1), the displaced wh-element *who* is called a “filler”, and the “gap” is the canonical position in the sentence where the subject (in an SR) or the object (in an OR) would appear in a simple declarative sentence. The filler and gap 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 when processing ORs (e.g., Gibson, 1998, 2000¹). 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; see Saito (1985) for evidence of the existence of VP in Japanese). 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; also see Hawkins (1994) for an account based on the combination of linear and structural distance). The term “structural distance” describes a configurational property in a particular kind of representation of linguistic phrase structure, illustrated in Figure 1. We do not mean to suggest that the processing system constructs exactly those representations, but only that such representations capture something about how the words in a sentence must be linked during comprehension to arrive at the correct interpretation. Thus, we

use the term “structural distance” as shorthand for a property of the linking of words in the interpretation constructed by comprehenders. That property is more complex for ORs than for SRs, as illustrated in Figure 1.

(Figure 1 about here)

RCs in Japanese differ from those in English in several important ways (cf. Kuno, 1973; Tsujimura, 1996). Many 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 contrast, English RCs 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. An important consequence of these differences between Japanese and English is that the gap precedes the head noun filler in Japanese, while the gap follows the relative pronoun filler 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

\longleftarrow relative clause (RC) \longrightarrow	head noun	
	↓	
[__ 議員を	非難した]	記者
[__ giin-o	hinanshita]	kisha
[__ senator-ACC(USATIVE)attacked]		reporter
GAP		FILLER
<i>‘the reporter [(who) __ attacked the senator]’</i>		

b. Object relative (OR) in Japanese

[議員が	__	非難した]	記者
[giin-ga		hinanshita]	kisha
[senator-NOM(INATIVE)	__	attacked]	reporter
	GAP		FILLER
<i>‘the reporter [(who) the senator attacked __]’</i>			

Another syntactic feature of Japanese that is important in the processing of RCs is that Japanese, unlike English, is a “*pro*-drop” language, i.e., in contexts where English would normally use a pronoun, that pronoun can be omitted in Japanese. Subject-drop (3a) (note that *pro* stands for an omitted pronoun) is much more common than object-drop (3b) in Japanese (Ueno & Polinsky, submitted), but both can occur in certain kinds of discourse.

(3) a. Mono-clausal sentence with subject *pro*

<i>pro</i>	議員を	非難した	
<i>pro</i>	giin-o	hinanshita	
<i>pro</i>	senator-ACC	attacked	

‘(I/you/he/she/we/they) attacked the senator’

b. Mono-clausal sentence with object *pro*

議員が	<i>pro</i>	非難した	
giin-ga	<i>pro</i>	hinanshita	
senator-NOM		attacked	

‘The senator attacked (me/you/him/her/us/it/them)’

Furthermore, Japanese has a clause type called “fact-clause”, which is a clause that modifies certain nouns such as ‘fact’, ‘news’, and ‘rumor’, as in ‘the fact that the reporter attacked the senator’. These fact-clauses are different from RCs in that they do not contain a gap, but are similar to RCs in that they follow the basic head-final word order of Japanese, making these fact-clauses 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 this particular usage of 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]’

These fact-clauses also differ from their English counterparts in that they allow *pro*-drop, as shown in (5).

(5) a. Fact-clause with subject *pro*

[<i>pro</i>	議員を	非難した]	事実
[<i>pro</i>	giin-o	hinanshita]	jijitsu
[<i>pro</i>	senator-ACC	attacked]	fact

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

b. Fact-clause with object *pro*

[議員が	<i>pro</i>	非難した]	事実
[giin-ga	<i>pro</i>	hinanshita]	jijitsu
[senator-NOM		attacked]	fact

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

Because there is no overt relativizer/complementizer, there is temporary ambiguity about whether a clause is a fact-clause or a RC, and the fact that the nominal heads of noun phrases (nouns modified by RCs and fact-clauses) do not appear until the very end adds to this ambiguity.

Another source of ambiguity in the processing of Japanese RCs is that there is yet another type of structure, the adjunct clause, which is also similar to RCs and fact-clauses on the surface. In this case it is the complementizer of the adjunct clause (e.g., 'because'/'after'/'if' clause) that appears at the end, as shown in (6).

(6) Because-clause

記者が	議員を	非難した	ので
kisha-ga	giin-o	hinanshita	node
reporter- NOM	senator-ACC	attacked	because

'Because the reporter attacked the senator'

Like fact-clauses, these adjunct clauses also allow *pro*-drop, as shown in (7).

(7) a. Because-clause with subject *pro*

<i>pro</i>	議員を	非難した	ので
<i>pro</i>	giin-o	hinanshita	node
<i>pro</i>	senator-ACC	attacked	because

'Because (I/you/he/she/we/they) attacked the senator'

b. Because-clause with object *pro*

議員が	<i>pro</i>	非難した	ので
giin-ga	<i>pro</i>	hinanshita	node
senator-NOM		attacked	because

'Because senator attacked (me/you/him/her/us/it/them)'

Taken altogether, the combination of the prenominal position of multiple kinds of noun-modifiers such as RCs and fact-clauses, the absence of overt relative markers, and the possibility of *pro*-drop in simple and complex clauses means that there can be considerable temporary ambiguity about whether a sequence of words constitutes a RC, a simple mono-clausal sentence, a fact-clause, or an adjunct clause. In other words, a RC like (2a) or (2b) could initially be interpreted as a simple mono-clausal sentence as in (3a) or (3b), as a fact-clause as in (5a) or (5b), or as a because-clause as in (7a) or (7b). It is only when the head noun finally appears that it becomes clear that the word string must constitute a RC modifying the head noun. That the sequence of words preceding the head noun constitute a clause modifying it is signaled by the appearance of a noun following the verb, since verbs are always clause-final in Japanese. In other words, if a verb is followed by a noun, the verb must be the end of a prenominal clause modifying that noun. The possibilities that the sentence has a fact-clause or a because-clause can only be ruled out when the verb is followed by a noun that is neither a 'fact'-type noun nor a complementizer such as 'because'.

The differences between Japanese and English RCs have several consequences for how Japanese RCs could be comprehended. First, as discussed above, Japanese RCs are temporarily

ambiguous. In English, comprehenders usually know that a sequence of words is part of a RC as they hear or read them because there are many cues available early on, most notably a relative pronoun immediately following a head noun. In contrast, Japanese comprehenders cannot be certain that there is a RC noun structure until the appearance of its very last word, the head noun. Another important difference is that in Japanese, it is SRs that involve a longer linear gap-filler distance, as shown above in (2), while in English it is ORs that involve a longer linear filler-gap distance, as shown above in (1).

While there are many surface 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), but otherwise the structure is the same in both languages. (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 inconsequential for our analysis since our arguments and conclusions are consistent with both of these possibilities.) 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)

Alternative Accounts of Relative Clause Processing Difficulty

Our studies are specifically designed to distinguish between linear and structural distance accounts of the relative difficulty of processing SRs and ORs, but a number of other accounts have been proposed to explain the difficulty of processing English and Japanese ORs.

Accessibility Hierarchy

A classic account of the relative difficulty in processing ORs is the notion of the “Accessibility Hierarchy”. After examining about fifty languages, Keenan and Comrie (1977) proposed that a hierarchy universally determines the degree of accessibility of a particular grammatical function for RC formation, in the order of Subject > Direct Object > Indirect Object > Oblique > Genitive > Object of Comparison. One basis for the proposed hierarchy is that the relativization of the subject noun (thus forming an SR) is permitted in more languages than is the relativization of an object noun (thus forming an OR). Keenan and Comrie also argued that the Accessibility Hierarchy is directly related to processing cost, but left open the question of whether SRs are easier to process because subjects are more accessible, or are more accessible because they are easier to process.

Frequency

Another account for the differences between the processing of SRs and ORs is based on the general frequency of SRs and ORs in natural discourse. Perhaps SRs are easier to process because they are more frequent. However, the idea that the frequencies of occurrence of particular constructions directly influence their processing cost has proved to be controversial (e.g., Gibson,

Schütze, & Salomon, 1996; Schlesewsky, Franselow, Kliegl, & Krems, 2000; Bornkessel, Schlesewsky, & Friederici, 2002; also see Kwon, Polinsky, & Kluender, in prep. for Korean RCs). In addition, while there was an early report of SRs occurring more frequently than ORs in written English texts (Keenan, 1987), a recent report based on a much larger corpus (Roland, Dick, & Elman, in press) indicates that whether it is English SRs and ORs that are more frequent in natural discourse depends on the type of corpus that is analyzed. In contrast to written corpora, spoken corpora tend to include more ORs than SRs (also see Fox, 1987). Even if global frequency does have some influence on processing cost, the same circular question remains: are SRs easier to process because they are more frequent, or are they more frequent because they are easier to process?

Perspective Shift

Another account suggested as an explanation for why ORs are more difficult to process than SRs is “perspective shift”. The perspective of a clause is generally taken from its subject, and on this account it is costly to shift perspective within a sentence (MacWhinney, 1982). For instance, in a sentence with an SR modifying the main clause subject noun as in (8a), no perspective shift is required because the perspective remains the same (*the reporter’s*) throughout the sentence. In contrast, when an OR modifies the main clause subject as in (8b), two perspective shifts are required: one shift from the subject of the main clause, *the reporter*, to the subject of the RC, *the senator*, and then another shift back to the main clause subject after the RC. These shifts are argued to be the source of processing difficulty for ORs.

- (8) a. Subject relative (SR) modifying the subject noun

The reporter [who __ attacked the senator] disliked the editor.

- b. Object relative (OR) modifying the subject noun

The reporter [who the senator attacked __] disliked the editor.

In contrast, when a RC modifies the main clause object as in (9), only one perspective shift is required regardless of whether the RC is a SR or an OR, since the perspective shifts from that of the main clause subject *the reporter* to that of the RC subject: *the editor* in an SR (9a) or *the senator* in an OR in (9b).

- (9) a. Subject relative (SR) modifying the object noun

The reporter disliked the editor [who __ attacked the senator].

- b. Object relative (OR) modifying the object noun

The reporter disliked the editor [who the senator attacked __]

One problem with the perspective shift account is that it predicts that there should be no difference in difficulty between SRs and ORs modifying main clauses objects since only shift is required in both cases, but ORs modifying object nouns are reported to be harder than SRs modifying object nouns (e.g., Sheldon, 1977), suggesting that perspective shifts alone cannot account for the difficulty of ORs.

Referential Account

Lastly, while we have been focusing on the analysis of Japanese RCs based on syntactic dependencies, some linguists have proposed that Japanese RCs do not involve any syntactic movement, but rather that the gaps are actually *pros* (null argument pronouns as discussed in (5) above) instead of traces left by syntactic movement (e.g., Comrie & Horie, 1995; Matsumoto, 1989; Murasugi, 2000). In this interpretation, SRs involving subject *pros* might have an advantage

over ORs involving object *pros* because subjects tend to have higher prominence in the discourse than objects. While we do not know of any studies that have compared the processing of Japanese RCs and other constructions involving *pros*, a recent series of reading time and ERP studies (Kwon, Kluender, Polinsky, & Kutas, 2007b) has compared the processing of RCs and because-clauses with subject and object *pros* (similar to (2) vs. (7) in our examples) in Korean, which have very similar syntactic properties to Japanese. The results show some differences between the processing of RCs and sentences involving *pros*, suggesting that Korean (and perhaps Japanese?) RCs may not involve *pros*. We will return to this point in the General Discussion section.

Overall

Each of the factors described above may play some role in the differences in the difficulty of SRs and ORs, but each of the accounts has its own drawbacks. For the sake of simplicity, we will focus on distance accounts for much of the remainder of the paper, but will return briefly to a possible referential account of Japanese RCs at the end of the General Discussion.

Previous ERP Research on English Filler-gap Dependencies

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), which is observed between the filler and its 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, 1993a, b; King & Kutas, 1995). For instance, King and Kutas (1995) reported a bilateral frontal slow negative potential in response to ORs in English (10b) when compared to SRs (10a), starting after the relative pronoun and continuing throughout the relative clause. In addition, there was a phasic LAN effect immediately following the gap in the OR condition (10b), i.e., at the main verb *admitted*.

- (10) a. SR *The reporter [who __ harshly attacked the senator] admitted the error.*
 b. OR *The reporter [who the senator harshly attacked __] admitted the error.*

Other recent studies have reported P600 effects at the gap location instead of or in addition to LAN effects. The P600 is a positivity that typically peaks 600-900 ms after stimulus onset and is typically broadly distributed over the head with a bilateral centro-posterior maximum. For instance, Kaan, Harris, Gibson, and Holcomb (2000) compared embedded yes-no and wh-questions as shown in (11), and found P600 effects at the pre-gap main verb position (*imitated* in this example) in the wh-conditions ((11b) and (11c)).

- (11) 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 audience's amusement.*
 c. *Emily wondered [which pop star the performer in the concert had imitated __] for the audience's amusement.*

Kaan et al. 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. Another recent study (Gouvea, Phillips, Kazanina, & Poeppel, submitted) has confirmed Kaan et al.'s finding that P600 can reflect syntactic

integration difficulty in *wh*-constructions without any ungrammaticality or garden-pathing. In addition, that study and a few others 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).

Previous Reading Time Research on Japanese and Korean RCs

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.² However, a few studies have investigated Japanese and Korean RCs using reading time measures (Ishizuka, Nakatani, & Gibson, 2003³; Miyamoto & Nakamura, 2003; Nakamura & Miyamoto, in prep.; Kwon, Polinsky, & Kluender, 2006, in prep.; Kwon et al., 2007b). 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 they have longer linear distance only in English, these results suggest that structural distance may be the more important factor.

Predictions

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 for 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 in Japanese until the filler appears at the end of the relative clause, it is possible that there will not be any differences between SRs and ORs until the head noun position or later. If linear distance is an important factor, Japanese SRs should have a heavier processing load than ORs, as indexed by these ERP effects. However, if structural distance is the more important factor, 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 sentences with SRs and ORs, 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 either 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. Stimuli consisted of pairs of sentences with singly-embedded Japanese (a) SRs or (b) ORs, as shown in Table 1. Note that on the surface, the only difference between SR and OR conditions was the case marker on 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 structure and the same number of words as the examples shown in Table 1.

(Table 1 about here)

SRs and ORs were compared to one another directly, rather than to another kind of baseline sentence, because any other sentence starting with the same kinds of word in the same sequence as our SRs and ORs would have to involve *pro*-drop, as shown above in (3), (5), and (7). The processing of *pro*-drop has not been much studied, but one recent series of experiments on Korean (Kwon et al., 2006, 2007b, in prep.) suggests that both subject and object *pros* incur their own processing costs. The language does not provide a simple baseline sentence type with the right kinds of properties, so we will only be able to draw conclusions about the difficulty of SRs and ORs relative to one another.

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 perspective shift (MacWhinney, 1982) and case-mismatch (Sauerland & Gibson, 1998). As discussed in the Introduction, SRs modifying the subject noun require no perspective shift and thus may be easier than ORs modifying the subject noun, which require multiple perspective shifts (MacWhinney, 1982). In the present stimuli the head noun is an oblique adjunct with dative-topic marking instead of the main clause subject, which should yield a similar degree of perspective shift between the main and relative clauses for both SRs and ORs. This approach also controlled for a related potential

confound regarding the case-marking on the head noun, which indicates its grammatical function in the main clause rather than its grammatical 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 and the case-marking within the RC has been argued to lead to processing difficulty (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 approximately 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 vs. nominative) and ORs (dative-topic vs. accusative).

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.

Norming studies. Three norming studies were conducted to examine various aspects of experimental sentences. Norming Study 1 was conducted in order to confirm that nouns used in 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 2, or Norming study 2 or 3) 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 [$F_1(1,18) = 1.02, p > .1$; $F_2(1,78) = 2.58, p > .1$] whether the head noun was used as the subject (mean rating = 4.4) or the object (4.3).

Norming Study 2 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, a fact-clause, or an adjunct 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 (as in (3) above), a fact-clause (5), an adjunct clause (7), 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 non-RC construction, 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. 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; also see Norming Study 3 below). 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. 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 68 different verbs used in the RC of the stimulus sentences were combined with 32 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 (but did not participate in Norming Study 1 or 3), 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.⁴ 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.

Finally, Norming Study 3 was conducted to investigate how likely it was that the fragments for the stimulus sentences were going to be interpreted as RCs (as opposed to other possible constructions) at the RC verb, which is the first position participants would recognize a missing argument for ORs (and possibly for SRs, if they have speculated a scrambled OSV word order). The sentence fragments up through the RC verb of SRs and ORs (see 12) and the fragments up to word 3 of the filler sentences were presented in the same order as in List 1 or List 2 of the stimulus sentences.

(12) a. SR fragment

新任の	議員を	非難した
shinninno	giin-o	hinanshita
<i>new</i>	<i>senator-ACC</i>	<i>attacked</i>

b. OR fragment

新任の	議員が	非難した
shinninno	giin-ga	hinanshita
<i>new</i>	<i>senator-NOM</i>	<i>attacked</i>

Ten native speakers of Japanese who did not participate in either Experiment 1 or 2 or Norming Study 1 or 2 were assigned to one of the two lists and were asked to complete the sentences as they wished, based on their first impression. Participants were also told that if they felt a certain fragment was already a complete sentence, they could just add the Japanese version of a period and end the sentence there. This was done to let participants choose a mono-clausal construction if they wished. The total of 400 SR fragments (40 completions x 10 participants) and 400 OR fragments (40 completions x 10 participants) were completed. Collapsed across participants, an overwhelming majority of both SR (80%) and OR (93%) fragments were completed as RCs. The higher instance of RC completions for OR fragments than for SR fragments [$t(9) = 2.99$, $p < .05$]

was probably because postulating object *pros* for non-RC constructions was less natural than postulating subject *pros* for non-RC constructions, as discussed above with respect to Norming Study 2. (See Nakamura and Miyamoto (in prep.) for a similar result.) Non-RC constructions produced by the participants included fact-clauses (4% for SR fragments, 2% for OR fragments), adjunct clauses (6% SR, 2% OR), and mono-clausal sentences (10% SR, 4% OR). This pattern of results suggested that experimental sentences were very likely to be interpreted as RCs at the RC verb.

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 multi-word 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) (F_1) or “item” (with “item group” as a nested factor) (F_2) as a random factor. An alpha level of .05 was used for all statistical tests, with a p-value of $<.10$ considered marginally significant. In addition, 95% confidence intervals were calculated on pairwise contrasts of interest (Loftus & Masson, 1994).

Results

Comprehension Task Accuracy

The mean correct response rate to all the comprehension questions across participants was 92% (range 81-100%, S.D. 5%). Thus no participant’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%) [$F_s < 1$].

Reading Times

(Figure 3 about here)

Figure 3 shows the mean trimmed reading times by sentence position for each word. Within the RC (words 1-3), although SRs and ORs were identical at the first word (the modifier ‘new’ in Table 1), SRs took 34 msec longer to read than ORs at this position, exceeding the 95% confidence interval on the difference of 31 msec by subjects and 23 msec by items [$F_1(1,38) = 4.74$,

$p < .05$; $F_2(1,78) = 8.10$, $p < .01$] (see Discussion). There was no significant difference at the second word position (the RC noun, ‘senator-ACC/NOM’) [$F_s < 1$]. At the third word (the RC verb, ‘*attacked*’), however, SRs took 39 msec longer than ORs, exceeding the 95% confidence interval on the difference of 27 msec by items, but not the 52-msec confidence interval by subjects [$F_1(1,38) = 2.27$, $p > .1$; $F_2(1,78) = 8.25$, $p < .01$].

In the post-RC region (words 4-7), at the head noun positions (‘*reporter-DAT-TOP*’) ORs took 47 msec longer than SRs, exceeding both the 39-msec 95% confidence interval on the difference by subjects and the 42-msec 95% confidence interval by items [$F_1(1,38) = 5.60$, $p < .05$; $F_2(1,78) = 4.79$, $p < .05$]. At the following fifth word position (‘*long-term*’), reading times were still 25 msec slower in ORs than in SRs, but this difference was only marginal and did not exceed the 29-msec 95% confidence interval by subjects or the 28-msec confidence interval by items [$F_1(1,38) = 2.89$, $p < .1$; $F_2(1,78) = 3.30$, $p < .1$]. There were no significant differences later in the sentence (word 6, [‘*colleague-NOM*’, $F_s < 1$]; 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 (words 4-7) 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 at the first word position in SRs must have been due to noise, given that the word in that position was identical across conditions. The slowdown did not extend to the following word and 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 on the noun (nominative *-ga* in ORs and accusative *-o* in SRs) did not lead to reading time differences, even though it is more typical to start a sentence with a nominative- than an accusative-marked noun. However, in the self-paced reading paradigm, effects are often delayed a word, so it is possible that the accusative-marked noun in SRs caused a slowdown one word later at word 3. Although this difference was reliable only by items, we do not want to dismiss it because a similar trend has been reported in other reading time studies in Japanese and Korean (Miyamoto & Nakamura, 2003; Kwon et al., 2006, 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.) argued that the appearance of an accusative-marked noun suggested that the subject was missing in the SRs, leading to additional processing cost compared to ORs. A similar process might have taken 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 collapsed 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., 2006, 2007b, 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), due to the extra topic-marker in addition to the dative-marker. However, word length cannot 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 the pattern of results was identical to the one shown in Figure 3. Long reading times on the head noun also cannot be attributed to the frequency of the head nouns, since the head nouns were actually slightly, though not reliably, more frequent (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)⁵. The long reading times are also not 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 overall at the head noun position seem most likely to be due to the general difficulty of processing the RC structure for both SRs and ORs. At this point in the sentence, the parser should be constructing the RC structure and filling the gap with the head noun for both SRs and ORs.

According to the results of Norming Study 3, the effect of RC processing might have been expected to begin at the preceding word, the RC verb, since fragments up through that verb were almost always completed as RC structures. We did find a difference between SRs and ORs at the RC verb (by items only), but we argued above that it was most likely spillover from processing the

preceding word, whose case-marking differed across conditions. On the same logic, it is possible that the longer reading times on the head noun in ORs reflect processes that began at the preceding word, the RC verb. At any rate, the slow reading times at the head noun for ORs provide 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. In addition, the reversal in direction of differences between SRs and ORs from the position following the noun whose case-marking differs across conditions to the head noun also replicates previous studies.

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, 1993a, b; 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.⁶ 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. The presentation rate of 650 ms per word is slower than rates 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*.) 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 scalp 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 and later algebraically re-referenced to the mean of the activity at the two mastoids. 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 10K Ω . The EEG was amplified with a bandpass of 0.01 to 30 Hz, digitized at 200 Hz, and stored for off-line analysis. Artifacts due to eye movement were removed 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 the time windows covering the RC region (words 1-4) and the post-RC region (words 4-7). The analysis epochs were 3050 ms long, 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, C5/6, CP5/6) 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 adopted 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 participants was 91% (range 84-98%, S.D. 4%). Thus no participant’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%) [$F_1(1,31) = 1.60, p > .1$; $F_2(1,78) = 1.02, p > .1$]. Notice that mean accuracy for the ERP experiment was 2-3% lower overall than that for the reading time

experiment, probably 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.

ERPs

Six percent of the data were rejected due to uncorrectable 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) in ORs. Figure 4 shows the RC region starting at the nominative/accusative-marked noun position (word 2), which is the first point of the sentence where the SR and OR sentences become different, with different case marking on the noun.

(Figure 4 about here)

To quantify the observation of the anterior negativity, ANOVAs were performed in the latency window of 300 to 600 ms after the onset of ‘*attacked*’ (with a 100 ms prestimulus baseline immediately preceding that word). ORs were reliably more negative than SRs in the midline array [$F(1, 31) = 6.68, p < .05$], and marginally so in the parasagittal array [$F(1, 31) = 3.04, p < .1$]. In addition, there was a reliable interaction between RC type and anteriority in the midline array [$F(2, 30) = 3.79, p < .05$], reflecting the anterior distribution of the effect. These effects indicated that ORs were more negative than SRs, especially at frontal regions. The anterior distribution of the negativity is illustrated with a series of isovoltage maps in Figure 4.

The anterior negativity that began at the RC verb continued throughout the response to the following word, the head noun, as shown in Figure 4. In order to determine whether any additional negativity was evoked by the head noun itself, another ANOVA was conducted on the 300-600 ms time window following the head noun, re-baselined on the 100 ms immediately preceding it. That analysis showed no reliable main effect of RC type nor any interaction of RC type and site. Thus, the anterior negativity observed in Figure 4 over the head noun seems to be a continuation of that evoked by the previous word, the RC verb.

Post-relative clause (RC) region. Figure 5 shows the comparison between RC types over the post-RC region, beginning at the head noun position (*'reporter-DAT-TOP long-term colleague-NOM existed'* in Table 1) and continuing through the rest of the sentence. Visual inspection of these four-word averages showed that ORs became more positive than SRs starting at about 500 ms after the onset of *'reporter-DAT-TOP'* and that this difference persisted across the rest of the sentence. The effect was widely distributed over the head, but was generally larger at centro-posterior regions. To quantify this observation, ANOVAs were performed in the latency window of 500 ms to 2950 ms poststimulus onset of *'reporter-DAT-TOP'*, capturing almost the entire extent of the waveforms shown in Figure 5. There was a reliable or marginal main effect of RC type in all three electrode arrays [*midline*: $F(1, 31) = 4.19, p < .05$; *parasagittal*: $F(1, 31) = 4.82, p < .05$; *temporal*: $F(1, 31) = 3.36, p < .1$], as well as a reliable RC type x anteriority interaction in the temporal array [$F(3, 29) = 3.38, p < .05$]. These effects indicated that ORs were more positive than SRs with a bilateral centro-posterior maximum scalp distribution of the difference. The series of isovoltage maps in Figure 5 shows that the effect started out weakly and strengthened over time while maintaining approximately the same centro-posterior distribution. However, ANOVAs on a 500-800 ms latency window for each word, including word as a factor, showed no interaction

between word position and RC type ($F_s < 2$), so the gradually increasing size of the effect across words that is apparent in Figure 5 was not reliable.

(Figure 5 about here)

Discussion

To summarize, ORs elicited greater bilateral anterior negativity than SRs beginning at the RC verb and continuing over the head noun in the RC region (Figure 4). Then in the post-RC region starting at the head noun and continuing to the end of sentence, ORs elicited greater centro-posterior positivity than SRs (Figure 5). In what follows, we will discuss each of these effects in turn.

Relative Clause (RC) Region (Figure 4)

The 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 name LAN), there have been several observations of bilaterally distributed versions (see Vos, Gunter, Kolk, & Mulder [2001], for a review of variation in the lateralization of anterior negativities across studies). In fact, almost all of the reports of LAN effects discussed in relation to filler-gap dependencies (Fiebach et al., 2001, 2002; King & Kutas, 1995; Phillips et al., 2005) show a bilateral negativity which may be larger on the left, with Kluender and Kutas (1993a, b) as the only exception. In addition, sustained anterior negativities between a filler and its gap tend to be quite bilateral (King & Kutas, 1995; Phillips et al., 2005), and there have been even reports of 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.

One possible interpretation of the anterior negativity observed in the RC region (as schematized in (13)) has to do with differences in the likelihood of subject- and object-drop in Japanese described in the Introduction.

(13) a. SR [____ *new senator-ACC attacked*] *reporter-DAT-TOP* ...

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

←——AN——→

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 Study 2. If the sentence is parsed as a simple monoclausal sentence (or a fact-clause/adjunct clause with *pro*-drop like (5) or (7)) 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; Martín-Loeches, Muñoz, Casado, Melcón, & Fernández-Frías, 2005) or morphosyntactic constraints (e.g., Coulson, King, & Kutas, 1998; Martín-Loeches et al., 2005), by non-preferred disambiguations of temporarily 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). To what extent all of these syntactic processes involve working-memory

load is controversial (cf. Coulson et al., 1998; Martín-Loeches et al., 2005), but at any rate, the anterior negativity found in the present study may be due to processing an apparently atypical construction with object-drop. Participants might have (incorrectly) recognized and reacted to such a construction at the RC verb position, with the effect carrying over to the following head noun position.

However, recall that our Norming Study 3 suggested that comprehenders were likely to be expecting a RC structure at the RC verb, as more than 80% of both SR and OR fragments up through the RC verb were completed as RCs. In addition, our stimulus sentences were presented with the Japanese version of a period at the end of each sentence. Thus although it was theoretically possible to end the SR/OR fragments as a mono-clausal sentence at the RC verb, the absence of a period signaled that more was coming. In addition, all of the sentences in the study had at least 6 words, so participants were unlikely to think that some sentences would end with only three words at the RC verb position.

Therefore, it seems more plausible to conclude that the anterior negativity reflects demands placed on working memory by filler-gap association (cf. Kluender & Kutas, 1993a, b). Under this interpretation, the parser recognizes the gap in ORs upon seeing a transitive-biased verb (*'attacked'* in (13b)) 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 has been dropped, or that the accusative-marked object noun is scrambled out of the default subject-object order), but this seems to be easier, as indicated by the ERP results. One possible interpretation is that dealing with the more deeply embedded object gap

in ORs results in a higher working memory load than dealing with the subject gap in SRs, supporting the idea that structural distance matters in RC comprehension.

Post-Relative Clause (RC) Region (Figure 5)

The centro-posterior positivity over the post-RC region is harder to clearly identify as one of the ERP components previously observed in sentence processing studies. The slowly developing divergence between SRs and ORs across this sentence region has a scalp distribution like that of P600, but a timecourse unlike the usual P600 timecourse. Thus, it is not clear whether or not this effect is related to previously observed P600 effects, or if it is an entirely different phenomenon. Given this, 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, 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 relatively difficult to integrate with their contexts lead to greater centro-posterior negativity (cf. Kutas & Van Petten, 1994; Kutas, Van Petten, & Kluender, 2006). N400 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 centro-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 could thus 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, then 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. As the isovoltage maps in Figure 5 show, there was a frontal component to the scalp distribution of the difference starting at the head noun, but the difference was primarily bilaterally posteriorly distributed. We cannot completely rule out the possibility that some of the difference at frontal sites may have been contaminated by re-baselining while there was continuing convergence back to baseline from the anterior negativity at frontal sites, but the effect at posterior sites cannot be explained in this way. In addition, if the frontal component of the effect were artifactual, it should decrease over time, which it does not. Finally, it is common for P600 effects to have a scalp distribution similar to that of the positivity observed here, including a frontal

component (Hagoort et al., 1999; Kaan & Swaab, 2003; Osterhout & Holcomb, 1992). Therefore, we now return to an interpretation of the difference between SRs and ORs 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. LAN effects have been reported in both phasic and long-lasting versions (e.g., Kluender & Kutas, 1993a, b; 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 *Be place prefer the was city it and sure be perfume*, and Casado, Martín-Loeches, Muñoz, and Fernández-Frías (2005) reported a long-lasting positive shift for a phrase structure reallocation process in Spanish. More recently, Gouvea, et al. (submitted) have reported a small long-lasting centro-posterior positivity (also with a prominent frontal component) at the point at which a syntactically well-formed long-distance wh-dependency is resolved in English. These effects are all argued to index syntactic processes typically related to the P600, and the positivity in our experiment may be a similar variant.

The continuous positivity starting at the head noun is more unambiguously 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, a fact-clause, an adjunct clause, or a RC. One question is whether the sustained positivity reflects reanalysis costs, as the P600 has been argued to do (e.g., Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994). That seems unlikely to be the case here, for the following reasons. First, as indicated by our Norming Study 2, the verbs used in the RC were highly transitive-biased, and it is unlikely that participants expected OR fragments (consisting of words such as *'new*

senator-NOM attacked' as in (12b)) to continue as an intransitive construction, requiring the participants to revise their analysis at the head noun position. Second, as Norming Study 3 indicates, OR fragments were more likely to be expected to be RCs than SR fragments were, probably because subject-drop is much more common than object-drop in Japanese. Thus SR fragments involving missing subjects (consisting of words such as '*new senator-ACC attacked*' (12a)) should have been more likely to make participants think that the sentence would continue as a non-RC (mono-clausal, fact-clause, or adjunct clause) construction than as an OR with missing a object, and this should have resulted in a higher reanalysis cost at the head noun position in SRs rather than in ORs.

Consistent with previous results obtained by Kaan et al. (2000), Phillips et al. (2005), Fiebach et al. (2001, 2002), and Gouvea et al. (submitted), this positivity seems to index the greater syntactic integration costs of integrating the object filler into the sentence. This fits well with the structural distance account of differences in processing difficulty between SRs and ORs. At the head noun position, the parser has to link the head noun filler with an appropriate gap position by searching in memory for the previously parsed element. Kaan et al. argued that an element with greater linear distance is less activated and thus harder to integrate with incoming input, as more resources are needed to reactivate it to allow for a successful integration. Our results indicate that the same thing is true for structural distance: an element that is more deeply embedded takes more resources for reactivation and successful integration. The object gap for an OR was harder to find than the subject gap for an SR because it is more deeply embedded and thus more structurally distant from the head noun, leading to more retrieval and integration costs.

In most (but not all) previous studies, P600 effects have been more phasic than our long-lasting effect, so one question is why our effect was so long-lasting. 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 completely clear that there is a RC, so if participants had not begun to do so earlier, this is where they have to recognize and construct a RC structure. It seems to have been especially difficult to do that for an object gap, presumably because it is more deeply embedded. A possibly related finding in Kluender and Kutas (1993a) 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.

Perhaps most comparable to the positivity we found is a positivity in one condition in Gouvea et al.'s (submitted) study. They found a small long-lasting centro-posterior positivity at the gap location in fully grammatical English wh-constructions. This effect was both smaller and longer-lasting than that in their other conditions with ungrammatical or garden-path sentences, and also smaller than for the sentences in Kaan et al.'s (2000) study. Although the difference was reliable only in the 300-700 ms latency window, it is apparent in their Figure 3 that the difference persisted throughout the 1300 ms shown in the plots, and looks likely to continue beyond that time since its size has not diminished by the end of the figure.

Models Linking ERP Components to Sentence Processing

Recently, several neurocognitive models have been proposed linking language comprehension subprocesses with particular ERP components (Ullman, 2001; Friederici, 2002; Hagoort, 2003, 2005; Bornkessel & Schlesewsky, 2006; Gouvea et al., submitted). These models generally concern how syntactic and semantic processes are differentiated and ordered. For instance, Ullman (2001) proposed that ruled-based syntactic processes are indexed by the (E(arly))LAN and are linked to procedural memory, while semantic processes are indexed by the

N400 and are linked to declarative memory. Late positivities are considered to be associated with controlled processes rather than with the automatic procedural processes indexed by the LAN. Friederici (2002) proposed a three-stage processing model: (1) constituent structuring (linked to the ELAN), (2) morphosyntactic (LAN) and semantic (N400) processing, and (3) reanalysis and repair (P600). Bornkessel and Schleewsky (2006) have recently proposed a more elaborated version of the three-stage model, the extended argument dependency model (eADM), and Hagoort (2003, 2005) has also proposed a Unification Model intended to explain both anterior negativities and posterior positivities. Most recently, Gouvea et al. (submitted) have proposed an explanation for variation in P600 across different kinds of sentences. In the next sections, we consider how our results relate to the latter three models, which are the ones most relevant for our study.

The anterior negativity in our data does not seem to fit any of these models' accounts very well, since they all tend to focus on anterior negativities evoked by morphosyntactic violations rather than those evoked by increased processing load in the absence of any violations. In the eADM, the LAN is related to failures in argument role assignment in Phase 2 of the three-phase model. The N400 and another negativity called a "scrambling negativity" are also associated with Phase 2 in the model. Since our negativity had an anterior distribution, we do not think it is likely to be an N400 effect, which normally has a right posterior distribution. It is also unlikely to be a "scrambling negativity" because the model links "scrambling negativity" to the processing of sentence-initial object NPs in languages such as German that do not allow subject-drop. Since subject-drop is not possible in German, the appearance of a sentence-initial object-marked noun signals that the sentence has an atypical scrambled OSV word order (Bornkessel et al., 2002; Rösler, et al., 1998; Schleewsky, Bornkessel, & Frisch, 2003). In our Japanese sentences, the anterior negativity was elicited at the verb position of ORs that were missing objects, and unlike

German, Japanese freely allows subject-drop. Finally, in the eADM the LAN is triggered by a mismatch in argument hierarchies (e.g., actor > undergoer, animate > inanimate) and/or agreement mapping, but our stimuli involved no mismatch in argument hierarchies, and Japanese has no agreement system. Thus, the LAN effect in the present study seems more consistent with an interpretation of increased working memory load evoked at the verb when it becomes clear that there is a missing object, which signals that there is either a dropped object or a complex structure involving an object-gap or object-*pro*.

Based on Vosse and Kempen's (2000) parsing model and a meta-analysis of ERP studies, Hagoort (2003, 2005) proposed that the anterior negativity is triggered by a failure to find an appropriate way to link an incoming word into the phrasal structure built for the sentence so far. Again, this does not fit particularly well with our anterior negativity, which again was triggered at the point where it becomes apparent that there is a missing object. However, as outlined in the Introduction, there are several possible structures that could accommodate a verb in that position, so it does not seem that there should be a failure to link the incoming verb in some way. However, all of the structures that could accommodate a verb at that point are relatively complex, and perhaps difficult enough to process that it could seem initially that there is no good way to accommodate the verb. We can only speculate on this point, since Hagoort does not address situations where it is difficult rather than impossible to find a way to link an incoming word into the structure built so far.

It is easier to see how our P600 effect fits with the existing models. Bornkessel and Schlesewsky (2006) fractionated late positive effects into the P600 and late positivity, and argue that the P600 is linked to a step called "Compute linking (agreement mismatch)" in Phase 2, and late positivity is linked to steps called "Generalized mapping" and "Well-formedness/repair" in

Phase 3. Our positivity could be related to the “Generalized mapping” step, during which all available sources of information are said to be integrated for argument interpretation. Bornkessel and Schleewsky mapped Kaan et al.’s (2000) P600 effect (“late positivity” in their terms) to this “Generalized mapping” step and stated that the positivity indexes increased integration difficulty between a verb and the object-filler. We may be able to translate this notion to Japanese RCs in terms of the integration difficulty between a verb and its arguments at the head noun position, in that the subject or object filler had to be linked to its gap position to be interpreted with the RC verb, and the more structurally distant object gap took more resources for activation and caused higher integration cost.

In Hagoort’s (2003, 2005) model, P600 amplitude is related to the time it takes to settle on one of several competing alternative structures, and he suggests that complexity could be one factor influencing that time. Thus, our finding of a P600 triggered at the head noun in ORs can be explained as a complexity effect on this view, and we would argue that it is due to the greater depth of embedding of the object gap.

Most recently, Gouvea et al. (submitted) parametrically manipulated grammaticality and long-distance wh-dependency to sort out the conditions giving rise to P600. They found the largest P600s when sentences were ungrammatical (preceded by anterior negativity in those conditions), but as described earlier, they also found a P600 effect that was comparable to ours, in their condition with fully grammatical sentences containing a long-distance wh-dependency. They proposed that P600 amplitude is influenced by the number and type of syntactic relations under consideration at a given point, an idea that is similar to Hagoort’s (2003, 2005) proposal that P600 amplitude is driven by how easy it is to settle on one structure from among multiple competing candidates and then unify that structure with the structure of the sentence up to that point. Again,

our P600 effect can be easily accommodated on this view as being due to greater depth of embedding leading to more difficulty unifying the chosen structure with what precedes it.

General Discussion

ORs vs. SRs

The two experiments reported here both suggest that Japanese ORs are harder to process than SRs. Starting at the head noun position, which clearly signals the RC structure, both reading times and ERPs showed extra processing costs for ORs, and those effects continued to the end of the sentence in the ERP data.

There appears to be one discrepancy between the two experiments with respect to the results at the RC verb. While there was a trend for slower reading times in SRs than in ORs at the RC verb in Experiment 1, suggesting that SRs had a higher processing load at that point, there was more anterior negativity at the RC verb in ORs than in SRs in Experiment 2, suggesting a higher processing load for the ORs. One solution would be to dismiss the reading time effect at that word since it was not reliable by subjects. However, we have not done that because the effect is consistent with similar effects at similar word positions in a couple of other reading time studies of Japanese and Korean (Miyamoto & Nakamura, 2003; Kwon et al., 2006, in prep.), suggesting that there may be something small but consistent going on across studies. Instead, we speculated in the discussion of Experiment 1 that one factor contributing to the longer reading times in SRs in the Japanese and Korean studies might be spillover from the immediately preceding accusative-marked noun in SRs, since sentence-initial accusative-marked nouns are not typical, and since effects in self-paced reading times often seem to be delayed a word.

Linear vs. Structural Distance

Our reading time experiment replicated the results of previous studies finding that Japanese and Korean ORs took longer to read than SRs starting at the head noun position. Our ERP experiment further showed similarities in the ERP components elicited by Japanese ORs and those elicited by English object filler-gap dependencies in previous studies: anterior negativity evoked within the relative clauses followed by centro-posterior positivity when the gap is filled, although the posterior positivity was more gradual and long-lasting for Japanese. Thus, both of our experiments showed ORs to be harder than SRs, supporting the idea that structural distance is more important than linear distance in relative clause comprehension.

It is difficult to know how similar the processes underlying the anterior negativity in our study are to the processes underlying anterior negativities evoked by fillers in English filler-gap constructions. In English, the filler precedes the gap so that it is obvious that there is a long-distance dependency, while in Japanese it is not certain that there is a gap until the filler arrives. However, the appearance of a strongly transitive verb after just one noun phrase does make it clear that the sentence is something other than a simple mono-clausal sentences with all of its arguments explicitly present, and our Norming Study 3 showed that participants were much more likely to be expecting a RC continuation than any other kind of structure at the RC verb. We cannot completely rule out the possibility that the anterior negativity was instead evoked by the atypicality of an accusative-marked sentence-initial noun, but we think it most likely to reflect an expectation for some kind of long-distance dependency triggered at the RC verb.

We can say with more certainty 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. Although this effect was smaller and longer-lasting than P600 effects in most

previous studies, we are encouraged by the somewhat similar effect found by Gouvea et al. (submitted) in grammatical sentences with wh-dependencies to interpret our effect as coming from the P600 “family”. In any event, if we assume that the continuous positivity indicates greater syntactic integration cost for ORs, both ERP and reading time data are most consistent with a structural rather than linear distance account of RC processing difficulty in Japanese.

An Alternative Referential Interpretation

Recall from the Introduction that some linguists have proposed that Japanese RCs involve null pronouns (*pros*) instead of traces left by syntactic movement (e.g., Comrie & Horie, 1995; Matsumoto, 1989; Murasugi, 2000). On this account, the gap in the RC would be interpreted by the same mechanisms as a pronoun, either by associating it with an entity in the discourse or by linking it with the head noun in the absence of other plausible discourse referents. Then rather than gap-filler distance (either linear or structural), what would actually matter is that the subject *pro* is easier to link with the head noun than the object *pro* is, perhaps due to its discourse prominence. 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 the reference is resolved. In addition, some recent work on Korean ORs, SRs, and because-clauses containing either object- or subject-*pros* (Kwon et al., 2006, 2007b, in prep.) has found similarities between SRs/ORs and subject/object-*pro* sentences: the main clause subject, which is also the head noun for the RCs, is read more slowly in both ORs and object-*pro* sentences than in SRs and subject-*pro* sentences, perhaps suggesting similar mechanisms in the processing of Korean SRs/ORs and subject-/object-*pro*. However, in other ways the two kinds of sentences did

not pattern together. When ORs and because-clauses with object *pros* were compared using ERPs, the results showed anterior negativity at the main clause subject (head noun) for ORs compared to because-clauses, as well as anterior negativity starting one word later and continuing to the sentence end for because-clauses compared to ORs (also see Kwon et al. (2007a) for an SR vs. OR comparison). Kwon et al. concluded that the results are most consistent with an account of Korean RCs in terms of syntactic filler-gap dependencies rather than the kind of referential dependencies in because-clauses. Given the strong similarity between Korean and Japanese, these results may also be taken as support for the same position for Japanese, but to be more certain, we need to investigate the processing of Japanese sentences involving *pros* (including both because- and non-because-clauses), as well as more types of filler-gap/gap-filler dependencies.

Conclusions

To conclude, our experiments have shown that Japanese ORs are harder to process than SRs, revealing higher processing costs for ORs than for SRs in both reading times and ERPs from the head noun to the end of the sentence. Thus, both ERP and reading time data are more consistent with a structural distance account than a linear distance account of differences between SRs and ORs, at least for Japanese RCs.

Our results also show that gap-filling difficulty is manifested as larger centro-posterior positivity in Japanese sentences in the same way that it is in English long-distance dependencies. Finally, there is also evidence that a cue suggesting some kind of gap or *pro* in a Japanese sentence, in the form of a strongly transitive verb following just one nominative-marked noun, triggers anterior negativity, similar to the triggering of anterior negativity by an obvious filler in English filler-gap sentences. Thus, we would argue that there is substantial similarity between the processing of English filler-gap constructions and Japanese gap-filler constructions. However,

given that the centro-posterior positivity we obtained is somewhat different from the typical P600 (smaller and more long-lasting), we plan to do further studies in Japanese following the example in Gouvea et al.'s (submitted) work on English, parametrically manipulating multiple P600-evoking properties of sentences to examine the nature of centro-posterior positivities cross-linguistically.

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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)

新任の議員が非難した/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/疎んじた/兄には/まともな/友達が/少なかった。
- 3a. 評判の/先輩を/妬んだ/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/疎んじた/生徒たちには/根暗な/人が/多かった。
- 5a. 高名な/人間国宝を/批判した/人々には/派手な/中年女性が/多かった。
- 6a. 無口な/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/見慣れてた/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/看護師には/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/うらやんだ/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/嫌がった/母親達には/高学歴の/インテリが/多かった。
- 12a. 几帳面な/書記を/ほめた/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/ほめた/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/うさん臭い/仲間が/ついていた。
- 16a. 聡明な/国王を/騙した/貴族には/ずる賢い/悪党が/ついていた。
- 17a. わがままな/ちびっこを/叩いた/保母さんには/適齢期の/長女がいた。
- 18a. タバコ屋の/未亡人を/なだめた/紳士には/たくさんの/知人がいた。
- 19a. 賢明な/店長を/信頼した/コックには/たくさんの/知り合いがいた。
- 20a. 排他的な/政治家を/排除した/運動家には/熱狂的な/支持者がいた。
- 21a. 屈託ない/跡継ぎを/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/見初めた/令嬢には/双子の/妹がいた。
- 23a. 近所の/囲碁仲間を/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/情婦がいた。
- 25a. 隣人の/亭主を/追い返した/舅には/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/嫁を/うるさかった/曾祖母には/ベテランの/家政婦さんが/ついていた。
- 28a. 石頭の/上司を/嫌がった/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/はすっぱな/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。

- 33a. 太っ腹な/スポンサーを/探し出した/監督には/有能な/マネージャーが/ついていた。
- 34a. せっかちな/連れ合いを/なだめた/細君には/しっかり者の/お手伝いさんが/ついていた。
- 35a. 皮肉な/教頭を/脅した/教員には/かんしゃく持ちの/奥さんが/いた。
- 36a. 若い/係長を/批判した/秘書には/酒好きな/女友達が/いた。
- 37a. 雅やかな/王子を/捕らえた/盗賊には/忠実な/手下が/いた。
- 38a. 売れっ子の/芸能人を/使った/カメラマンには/金持ちの/スポンサーが/ついていた。
- 39a. 小太りの/苛めっ子を/逃がした/わんぱく坊主には/のろまな/妹が/いた。
- 40a. エレガントな/ウグイス嬢を/引き止めた/立候補者には/有力な/政治家が/ついていた。
- 41a. 新人の/役者を/賞賛した/演出家には/元女優の/愛妻が/いた。
- 42a. のんべいの/父親を/叱った/娘には/病気がちな/母親が/いた。
- 43a. 夜勤明けの/医者を/呼び止めた/入院患者には/献身的な/女房が/ついていた。
- 44a. アメリカ人の/選手を/選んだ/コーチには/ヨーロッパ人の/奥さんが/いた。
- 45a. 昔の/アイドルを/けなした/マネージャーには/長年の/悪友が/いた。
- 46a. 地元の/名士を/からかった/芸者には/大富豪の/旦那が/ついていた。
- 47a. おませな/女の子を/追いかけ回した/母親には/小学校以来の/幼なじみが/いた。
- 48a. 男勝りな/姉を/どなり付けた/課長には/社内の/支持者が/少なかった。
- 49a. 野暮な/客を/無視した/バーテンダーには/素敵な/恋人が/いた。
- 50a. しっかり者の/お手伝いを/手なずけた/祖母には/単身赴任中の/息子が/いた。
- 51a. ずうずうしい/大家を/どなった/借主には/無責任な/親が/いた。
- 52a. 赤毛の/少女を/ナンパした/高校生には/幼なじみの/彼女が/いた。
- 53a. 気短な/板前を/非難した/板長には/有望な/後継者が/いた。
- 54a. しぶとい/ボクサーを/倒した/ライバル選手には/忠実な/ファンが/多かった。
- 55a. 野暮ったい/田舎者を/からかった/老人には/頼りない/長男が/いた。
- 56a. 非情な/借金取りを/追いまわした/ライターには/貧乏な/親戚が/いた。
- 57a. 怒りっぽい/夫を/殴った/息子には/同い年の/彼女が/いた。
- 58a. 敬謙な/信者を/訪ねた/神父には/多数の/協力者が/いた。
- 59a. 喧嘩早い/男子を/挑発した/教師には/意地悪な/悪友が/いた。
- 60a. 男勝りな/女課長を/いびった/係長には/強気な/妻が/いた。
- 61a. グラマーな/タレントを/おちょくった/司会者には/口うるさい/上役が/いた。
- 62a. 無口な/旦那を/追い払った/おかみさんには/うわさ好きな/おしゃべり仲間が/いた。
- 63a. 中堅どころの/小説家を/ひやかした/編集者には/美人の/秘書が/ついていた。
- 64a. 内気な/姉を/はげました/妹には/大好きな/アイドル歌手が/いた。
- 65a. 有名な/スター女優を/好んだ/監督には/青年層の/ファンが/多かった。
- 66a. やんちゃな/男の子を/見つけた/保母には/大学生の/息子が/いた。
- 67a. 手強い/敵を/殺した/兵士には/老齢の/母親が/いた。
- 68a. 直属の/部下を/裏切った/上司には/親しい/仲間が/少なかった。
- 69a. 暴れん坊の/ならず者を/捕らえた/ちんぴらには/手下の/弟分が/いた。
- 70a. せこい/小役人を/ののしった/市民には/幼い/娘が/いた。
- 71a. 野党の/議員を/支持した/官僚には/上流階級出身の/妻が/いた。
- 72a. 名家の/奥方を/追いやった/姑には/陰湿な/小姑が/ついていた。
- 73a. 勇敢な/名將を/切り倒した/兵士には/同郷の/戦友が/いた。
- 74a. 元気な/お袋を/追いかけた/配達人には/意地悪な/雇い主が/いた。
- 75a. 同室の/入院患者を/起こした/少女には/憧れの/医師が/いた。
- 76a. 古株の/ピアニストを/無視した/指揮者には/天才肌の/弟が/いた。
- 77a. 新人類の/部下を/避けた/次長には/受験生の/長男が/いた。
- 78a. 高德の/僧を/招待した/武士には/盲目の/長男が/いた。
- 79a. おませな/女の子を/ひやかした/腕白坊主には/厳格な/父親が/いた。
- 80a. 女たらしの/プレイボーイを/誘惑した/人妻には/無関心な/夫が/いた。

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 See the General Discussion section for the discussion of a recent ERP study on Korean RCs by Kwon et al. (2007a, b).

³ More recently, Ishizuka, Nakatani, and Gibson (2006) reported the opposite effect when Japanese SRs and ORs were presented in a discourse context.

⁴ 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%).

⁵ 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.

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.

Table 1

Stimuli

a. 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。
 [shinninno giin-o hinanshita] kisha-ni-wa naganenno aibou-ga ita.
 [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)

[新任の 議員が 非難した] 記者には 長年の 相棒が いた。
 [shinninno giin-o hinanshita] kisha-ni-wa naganenno aibou-ga ita.
 [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.

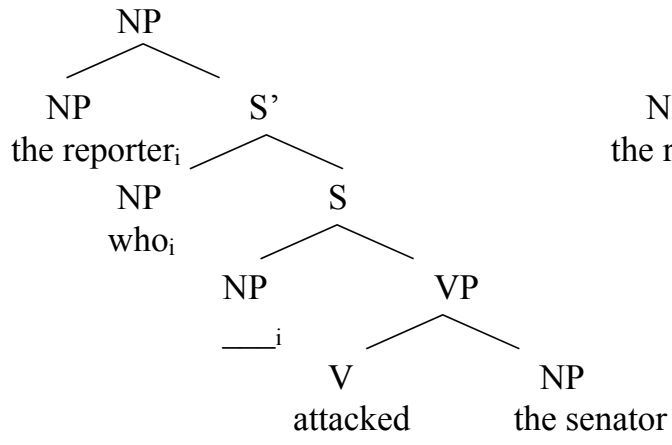
Figure 3. Mean trimmed reading times for each sentence position for subject relatives (SRs) and object relatives (ORs).

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. The isovoltage maps are based on the mean difference calculated as the OR minus SR conditions for the 300-600 ms intervals for each word.

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. The isovoltage maps are based on the mean difference calculated as the OR minus SR conditions for the 500-800 ms intervals for each word.

Figure 1

SR



OR

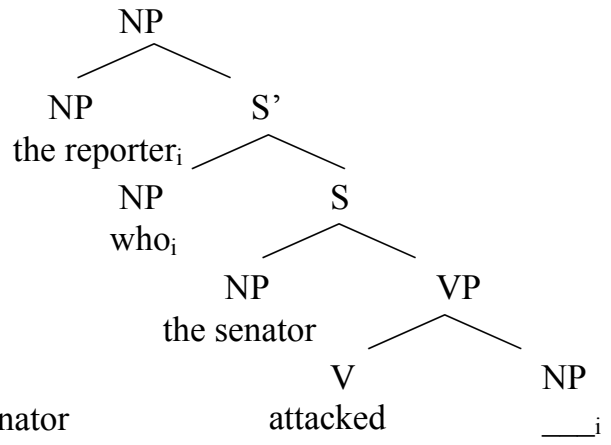
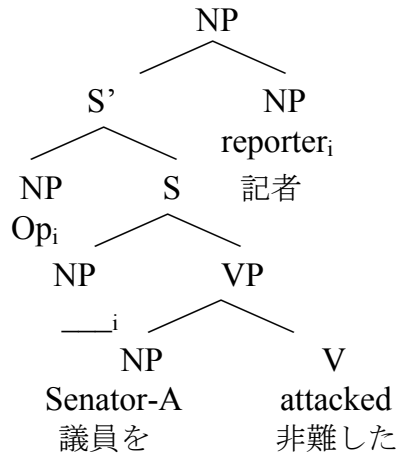


Figure 2

SR



OR

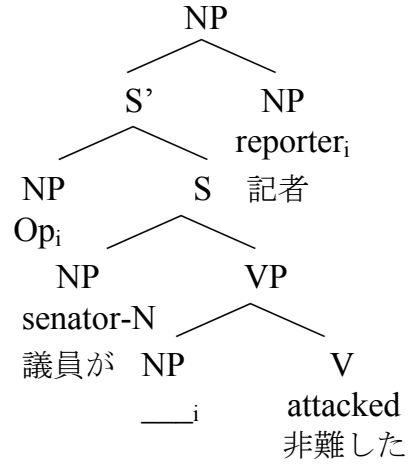


Figure 3

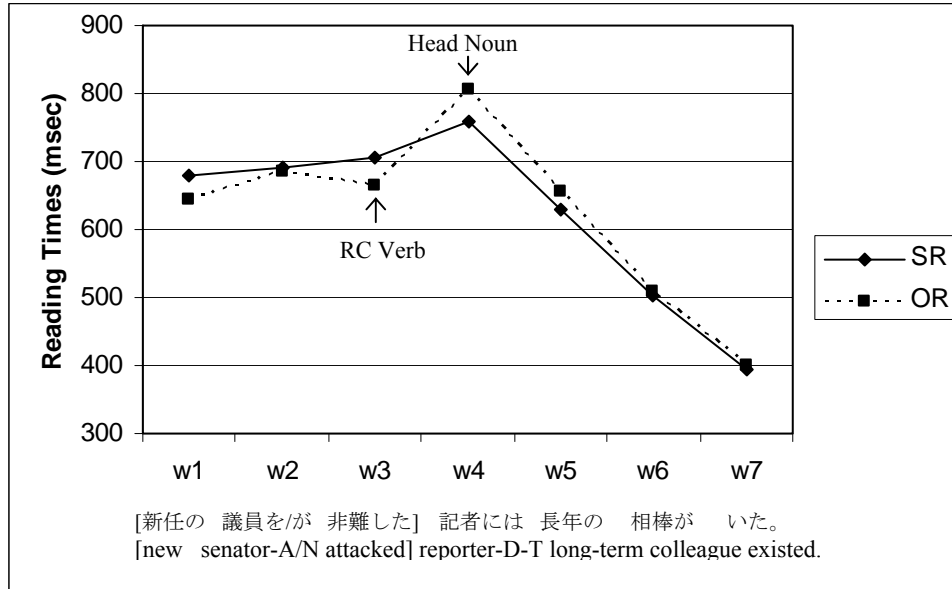
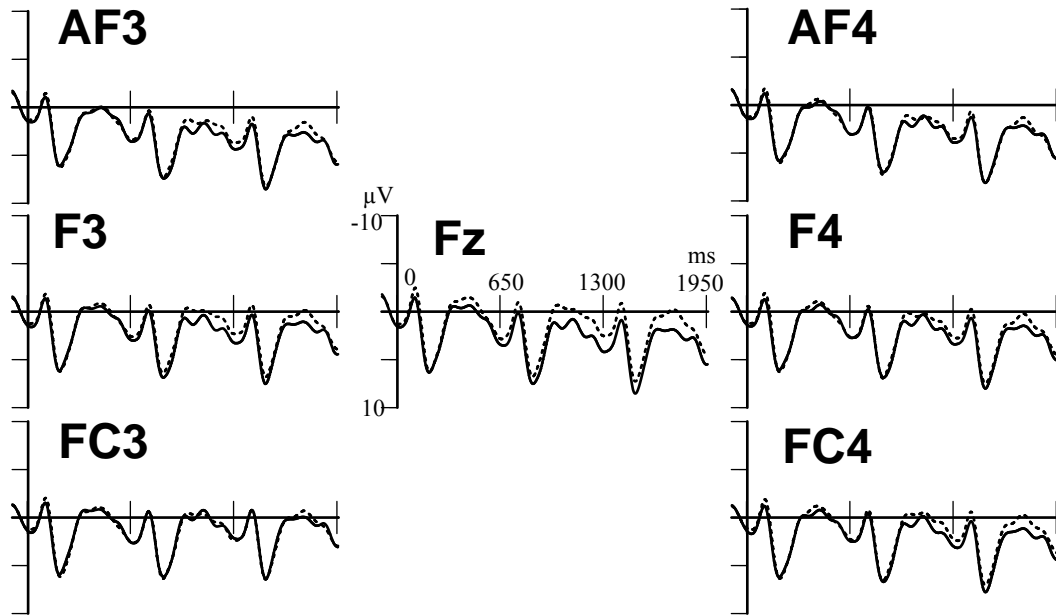


Figure 4

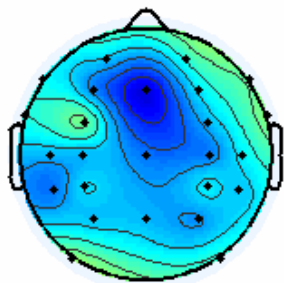


Subject Relatives (SRs)

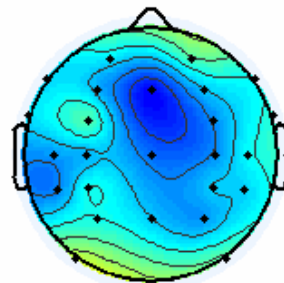
[新任の 議員を 非難した] 記者には 長年の 相棒が いた。
 [new senator-ACC attacked] reporter-DAT-TOP long-term colleague-NOM existed.

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



word 3
(attacked)



word 4
(reporter-DAT-NOM)

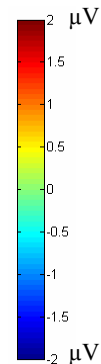
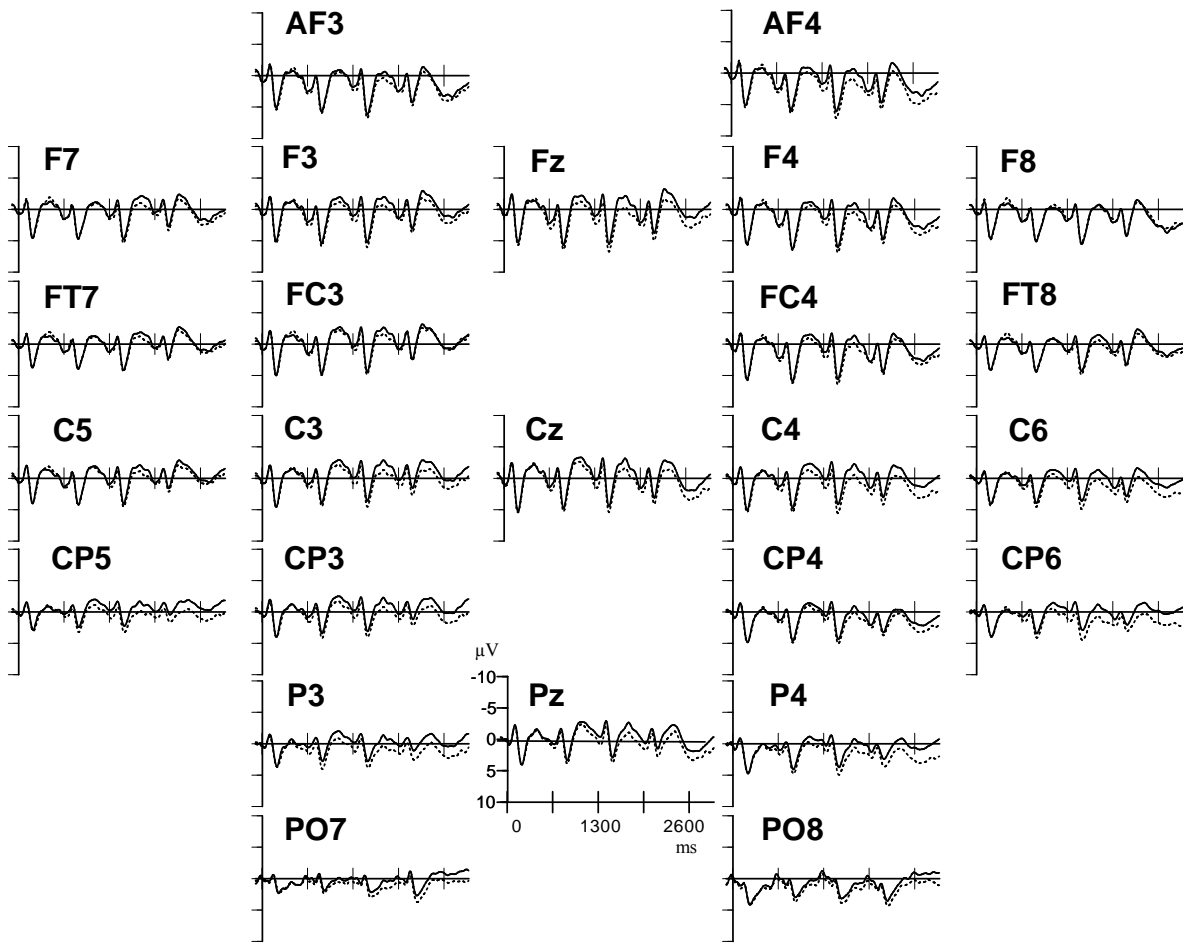


Figure 5



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

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

