Subject/object processing asymmetries in Korean relative clauses:

Evidence from ERP data

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Abstract

Subject relative (SR) clauses have a reliable processing advantage in VO languages like English in which relative clauses (RCs) and the syntactic gaps they contain follow the head noun. The question is whether this is also routinely true of OV languages like Japanese and Korean, in which RCs and their gaps precede the head noun. In reading time studies, Japanese and Korean, for example, show a consistent SR advantage, while Chinese, with basic VO word order but head-final RCs, shows conflicting results. We conducted an event-related brain potential (ERP) study of Korean RCs to help tease apart the typological factors that contribute to these differences: Korean is strictly head-final and marks its nouns for case like Japanese, but also marks the right edge of its RCs like Chinese. Previous ERP studies of RCs in Japanese (Ueno & Garnsey, 2008) and Chinese (Yang et al., 2010) point to a SR advantage, indexed by increased frontal negativity in response to object relatives (ORs) around the head noun position. Our results confirm this finding, indicating that brain responses to RCs are remarkably similar in VO and OV languages, but that ordering of the RC and its head noun localizes the response to different sentence positions. Our results also suggest that marking the right edge of the RC in Chinese and Korean affects the response to the following head noun. The consistent SR advantage found in ERP studies lends further support to the universal subject preference in the processing of relative clauses.
1 Introduction

At least since the pioneering work of Sir William Jones on Sanskrit at the end of the 18th century (in which he showed by means of comparisons with Latin and Greek that these languages were related), linguistic analysis has aimed at differentiating those aspects of the human language faculty that are universal in nature, i.e. shared by all known languages, from those that are specific to individual (groups of) languages. There has thus always been an inherent tension between emphasizing language-universal vs. language-specific properties in linguistic theorizing.

In recent years, it has become apparent from the results especially of neurophysiological studies that language-universal vs. language-specific aspects of language processing in the brain need to be differentiated in like manner, with a view to determining whether either predominates in a given language (see for example Bornkessel & Schlesewsky, 2006). Even though it deals specifically with the processing of relative clauses in Korean, the current study can be viewed as a contribution to this larger area of inquiry.

Both formal and functional approaches to the study of cross-linguistic variation have suggested that processing may play a role in shaping grammars. Various proposals in the formal tradition have equated rules of the grammar with computational operations of the parser (Miller & Chomsky, 1963; Fodor, Bever & Garrett, 1974; Bresnan & Kaplan, 1982; Berwick & Weinberg, 1983), while functionalists have also suggested that languages are structured in the ways they are because of processing constraints (Keenan & Comrie, 1977; Hawkins, 1990). We frame our discussion in these terms to highlight the fact that universal and specific properties of language can be identified and compared
not only in terms of language structure, but also in terms of language processing; moreover, the latter may underlie the former.

In subsequent sections, we review a number of typological properties hypothesized to affect the processing of relative clauses cross-linguistically. In section 1.1, we address more general structural properties, including the apparent processing advantage of subject relative clauses, in light of (a) the processing difficulty associated with pre-nominal relative clauses, (b) the processing differences between filler-gap vs. gap-filler dependencies in relative clauses, and (c) the effect of dropped arguments on relative clause processing. In section 1.2, we address structural properties of the major East Asian languages (Chinese, Japanese, and Korean) and their parametric variation with respect to: (a) headedness, (b) marking of noun phrases for case, and (c) marking of a pre-nominal relative clause at its right edge. We review two main types of theoretical explanation for the subject relative processing advantage in section 1.3, and discuss previous ERP results relevant to the processing of relative clauses in section 1.4.1 Predictions for our study based on this background are provided in section 1.5.

**1.1 The typology of relative clauses and consequences for processing**

Subject relative clauses (example (1a) in Table 1) are more common across the world’s languages than object relative clauses (example (1b) in Table 1) and other relative clause types (Keenan & Comrie, 1977).2
This is true regardless of whether a relative clause is post-nominal, i.e., follows its head noun (‘reporter’), as it does in English and related languages ((1) in Table 1), or pre-nominal, i.e. precedes its head noun, as is the case in many other languages including Chinese, Japanese and Korean, schematically represented with English lexical items in (2) of Table 1.

Keenan and Comrie’s claim that this pattern held because subject relatives are inherently easier to process has been substantiated in numerous studies across languages using a wide variety of psycholinguistic measures in English (self-paced reading time: King & Just, 1991; ERP: King & Kutas, 1995; PET: Stromswold, Caplan, Alpert, & Rauch, 1996; Caplan, Alpert, & Waters, 1998, 1999; Caplan, Alpert, Waters, & Olivieri, 2000; fMRI: Just, Carpenter, Keller, Eddy, & Thulborn, 1996; Caplan et al., 2002; Cooke et al., 2002; Constable et al., 2004; Chen, West, Waters, & Caplan, 2006; Caplan, Chen, & Waters, 2008; Caplan, Stanczak, & Waters, 2008; eye-tracking: Traxler, Morris, & Seely, 2002), in Dutch (Frazier, 1987), in German (Schriefers, Friederici, & Kuhn, 1995; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995, Bader & Meng, 1999; Schwartz, 2007), in Romance (Frauenfelder, Segui & Mehler, 1980; Holmes & O’Regan, 1981; Cohen & Mehler, 1996), in Hebrew (Friedmann & Novogrodsky, 2004; Arnon, 2005), in Turkish (Kahraman, Sato, Ono, & Sakai, to appear), and in Russian (Polinsky, to appear).

It has also been claimed in the typological literature that the choice of relative clause placement, viz. pre- or post-nominal, is influenced by processing efficiency. Languages in general tend to be consistent as to whether the head of a phrase occurs at its beginning or at its end (Greenberg, 1963); more critically, languages can be divided into V[erb]O[bject] and O[bject]V[erb] types (Dryer, 1992). For example, in VO languages
like English, verbs appear before their objects, and clauses therefore have VO word order. In robustly head-final languages like Korean, on the other hand, verbs follow their objects and clauses thus have OV word order. Similarly, VO languages like English have prepositions that precede their objects, while OV languages like Korean have so-called “postpositions” that follow them. The situation with relative clauses is not as straightforward. On the one hand, 98% of head-initial languages (Dryer, 1992) have head-initial (i.e., post-nominal) relative clauses ((1) in Table 1), consistent with the fact that they also have head-initial VO word order and prepositions. On the other hand, less than half of head-final languages (41%) with OV word order and postpositions also have head-final (i.e., pre-nominal) relative clauses ((2) in Table 1) (Dryer, 1992). The other 59% have head-initial (i.e., post-nominal) relative clauses instead, as in English (see also Hawkins, 1983; Lehmann, 1984). Overall, this leads to a higher percentage of post-nominal/head-initial relative clauses cross-linguistically. The underrepresentation of pre-nominal/head-final relative clauses across the world’s languages has been attributed to the fact that, given left-to-right sentence processing, pre-nominal/head-final relative clauses invite temporary misanalysis (Hawkins, 1990, 1999, 2004; see also Fodor, 1983). If the beginning of a relative clause is not marked as such, a sentence-initial relative clause like (2) in Table 1 can easily be misinterpreted as the main clause of the sentence. This misanalysis necessitates complex and costly revision processes later in the sentence when additional structural cues indicate that the sentence-initial string was in fact a relative clause (e.g., at the head noun ‘reporter’ in (2) of Table 1). The claim is that such structures are avoided cross-linguistically in order to minimize the burden of such processes.
The proper interpretation of any type of relative clause, either pre- ((2) in Table 1) or post-nominal ((1) in Table 1), additionally requires the mutual dependency of the head noun, which we will refer to as the “filler,” and its “gap” in the relative clause (i.e., the position where it would ordinarily occur in a declarative clause, indicated as “__i”) (Fodor, 1978). The filler must be interpreted at the gap position to determine its thematic role (i.e. whether it is the agent, patient, recipient, etc. of the action expressed by the relative clause verb) and grammatical function (i.e., whether it is the subject, object, indirect object, etc. of the relative clause), and the gap position receives its referential identity from the filler.

Thus pre- and post-nominal relatives also differ with respect to the relative ordering of the head noun filler (‘reporter’) and its gap: in post-nominal/head-initial relatives ((1) in Table 1), the filler precedes the gap, thus creating “forward” filler-gap ordering, while in pre-nominal/head-final relatives ((2) in Table 1), the filler follows the gap, creating “backward” gap-filler ordering. Each ordering presents its own processing challenges. A forward filler-gap dependency in a post-nominal/head-initial relative clause ((1) in Table 1) requires storage of the head noun ‘reporter’ in working memory and its retrieval at the gap position for thematic role assignment (i.e., as agent of the ‘attacking’ event). As outlined in section 1.3, this ordering has been shown to incur a number of processing costs. On the other hand, a backward gap-filler dependency in a pre-nominal/head-final relative clause ((2) in Table 1) may require storage of an unfilled gap (i.e., either the unspecified agent of the verb ‘attack’, as in ‘X attacked the senator’, or the argument and/or phrase structural representation of the entire relative clause) in working memory, and its subsequent retrieval at the head noun position, for establishing the
referent of the previously unspecified participant in the relative clause (i.e., who or what was it that did the attacking?). The difference in processing costs between these types of memory operations and those involved in a forward filler-gap dependency is still an open question.

Moreover, there is a further cross-linguistic difference that affects the processing of gap-filler ordering. As pointed out above, sentence-initial relative clauses like (2) in Table 1 whose left edge is not marked in any way can initially be misinterpreted as a main clause under certain circumstances. On the other hand, one might expect from English that a gap-filler dependency like (2a) in Table 1 would have a major impact on processing routines precisely because there is a missing argument in the initial clause. In other words, it might seem obvious that this is a relative clause structure because of the missing argument. The problem with this assumption is that the dropping of arguments is very common in languages like Chinese, Japanese, and Korean. In the case of Korean, subjects in spoken language are dropped 69.4% of the time, and objects 52.8% (Kim, 2000). Thus encountering a missing argument is not necessarily an indication that one is processing a relative clause.

In summary, subject relative clauses are more common across the world’s languages, and have been shown to be easier for language users to process in VO languages. In this study we investigate whether this is true of OV languages (e.g., Korean) as well. Languages tend to be consistent in their headedness properties, as observed in head-initial languages, of which virtually all those surveyed likewise have head-initial relative clauses. However, consistency of headedness does not seem to hold in the ordering of relative clauses in head-final languages, of which many exhibit head-
initial relative clauses instead. The difference in processing costs incurred by filler-gap ordering in head-initial relative clauses vs. gap-filler ordering in head-final relative clauses is another focus of our study.

1.2 Pre-nominal relative clauses across East Asian languages: Structure and processing

Subject relative clauses have been found to be more easily processed in languages with post-nominal relative clauses. For pre-nominal relative clauses, this same subject relative preference has been consistently replicated in Japanese (self-paced reading time: Kanno & Nakamura, 2001; Miyamoto & Nakamura, 2003; Ishizuka et al., 2003; ERP: Ueno & Garnsey, 2008) and in Korean (self-paced reading: Kwon, Polinsky, & Kluender, 2006, Kwon, 2008b; eye-tracking: Kwon et al., 2010. Studies of Mandarin, on the other hand, have produced far less straightforward results, with some studies finding a subject relative processing advantage, just as in English and Japanese (self-paced reading time: C. Lin & Bever, 2006; Kuo & Vasishth, ms.), while others have found an object relative processing advantage (self-paced reading time: Hsiao & Gibson, 2003; Y. Lin & Garnsey, 2007; Y. Lin, 2010; Gibson & Wu, under revision; maze-task: Qiao, Shen & Forster, submitted). For Cantonese, there seems to be a preference for object relatives at least in child language (Yip & Matthews, 2007).

One possible explanation for this is differences in basic word order. Japanese is strictly head-final, with SOV word order, as shown in (3) in Table 1. Chinese, on the other hand, exhibits mixed headedness. It is for the most part VO, with SVO word order and prepositions; however, it presents something of an anomaly with respect to its relative clause ordering. Of the 61 head-initial languages examined by Dryer (1992)
Chinese is the sole language that does not have post-nominal/head-initial relative clauses; it has pre-nominal/head-final relative clauses instead, as shown in (4) in Table 1.

However, there are further typological differences between Japanese and Chinese relative clauses that might account for why Japanese exhibits a consistent subject relative preference while Chinese does not. A feature that often correlates with strict head-final word order is the overt marking of noun phrases for case: note that in example (3) of Table 1, in Japanese all subject noun phrases are marked nominative (–NOM) and all direct object noun phrases accusative (–ACC); there is no equivalent case marking in example (4) of Table 1 for Chinese. On the other hand, Mandarin (but not Cantonese) exhibits a typological feature missing in Japanese, in that it marks the end (right edge) of its relative clauses with a clitic –de attached to the final word of the relative clause.

These three typological features (consistent headedness, case marking, and relative clause marking) could contribute to the difference in relative clause preferences shown by Japanese (subject preference) vs. Chinese (conflicting results) across studies. In this regard, Korean is a good test case, as it exhibits all three of these features ((5) in Table 1). Like Japanese, it is consistently head-final with SOV word order and pre-nominal/head-final relative clauses, and it also marks its noun phrases for case (i.e., subjects are marked –NOM and objects –ACC). However, similar to Chinese but unlike Japanese, Korean demarcates its relative clauses by attaching a morpheme -ADN to the clause-final verb.

INSERT TABLE 2 ABOUT HERE
To the extent that Korean patterns with Japanese in terms of its relative clause preferences and brain responses, this would confirm that the difference in the Japanese vs. Chinese results is attributable to parametric differences in the consistency of headedness and/or case marking. On the other hand, to the extent that Korean patterns with Chinese, this would indicate that relative clause marking constitutes a crucial typological factor. As a first step toward addressing these questions, we utilize an on-line measure that can provide both quantitative and qualitative information about the time course of relative clause processing in Korean, namely ERP methodology.

1.3 Theoretical accounts of the subject relative processing advantage

For ease of exposition, we group a variety of theoretical accounts of the subject relative processing advantage into two broad categories of explanation: those that deal with surface-level features such as the linear string, and those that refer to abstract levels of phrase structural representation.

In the first category are accounts that define the subject relative processing advantage in terms of activation and subsequent decay of a filler in working memory stores as material intervening is processed between filler and gap (or its subcategorizer, the relative clause verb ‘attacked’) in (1b) of Table 1. In this approach, processing difficulty increases as a function of filler-gap distance, either in terms of specific types of linguistic units in the linear string (e.g., Gibson 1998, 2000; Warren & Gibson, 2002) or in real time units (Lewis & Vasishth, 2005; Lewis, Vasishth, & Van Dyke, 2006). As soon as an unassigned filler (‘reporter’) is detected (at ‘who’), a corresponding gap is postulated in both subject (SRs; (1a) of Table 1) and object relative clauses (ORs; (1b) of Table 1). However, filler-gap distance is longer in ORs (1b) than in SRs (1a), as indicated
by the arrows. ORs in head-initial languages with forward filler-gap dependencies are therefore predicted and have been found to be more difficult.

In contrast, a gap precedes its filler and there is no relative pronoun to flag it in languages with pre-nominal relative clauses like Chinese, Japanese, and Korean. Moreover, since arguments are frequently dropped in these languages, the position at which the absence of an argument is detected will differ for subject vs. object relative clauses, rendering predictions based on linear/temporal distance more complex. For example, in Japanese and Korean (examples (3) and (5) respectively in Table 1) with SOV word order, a missing subject will be postulated at the sentence-initial, non-canonical NP-ACC (3a & 5a), while a missing object will be detected at a transitive verb lacking an internal argument (Table 1, 3b & 5b). In Chinese with SVO word order (example (4) in Table 1), absence of a subject will first be detected at the sentence-initial verb (Table 1, 4a) while a missing object will be postulated at the adnominal marker –de following the verb (Table 1, 4b; see footnote 8). Consequently, if linear/temporal distance is calculated with respect to the point at which a missing argument is detected, SRs should be more difficult to process than ORs due to their longer linear/temporal distance in all the East Asian languages, as indicated by the arrows in Table 1.

Processing models based on linear/temporal distance therefore predict a processing advantage for SRs in forward filler-gap dependencies in languages like English and an OR processing advantage in backward gap-filler dependencies in languages like Chinese, Japanese, and Korean.10 This prediction is consistent with studies of Chinese that report an OR processing advantage (Hsiao & Gibson, 2003; Y. Lin & Garnsey, 2007; Gibson & Wu, under revision; Qiao et al., submitted), but not with the
reported SR processing advantage in Japanese and Korean (Kanno & Nakamura, 2001; Miyamoto & Nakamura, 2003; Ishizuka et al., 2003; Ueno & Garnsey, 2008; Kwon, 2008b; Kwon et al., 2010) or with other studies of Chinese that report a SR processing advantage (C. Lin & Bever, 2006; Kuo & Vasishth, ms.).

In the second category of theoretical approaches are those that account for the SR/OR processing asymmetry in terms of more abstract levels of representation, namely grammatical relations (Keenan & Comrie, 1977) or phrase structure (O’Grady, 1997). Keenan and Comrie’s (1977) accessibility hierarchy (1) was originally proposed as a universal constraint on relative clause formation: if a language allows relativization on one grammatical position in this ordering, then it must also allow relativization on all grammatical positions to the left of that position on the scale shown in (1).

(1) Accessibility hierarchy
subject > direct object > indirect object > oblique > genitive > object of comparison

(Keenan & Comrie, 1977:66)

This is also argued to directly reflect ‘psychological ease of comprehension’ (Keenan & Comrie, 1977:88). In other words, a grammatical role higher on the accessibility hierarchy is argued to be easier to process and therefore more common cross-linguistically (see also Hawkins, 1999, 2004).

O’Grady’s (1997) phrase-structural distance hypothesis (2) accounts for the processing advantage of SRs in terms of the phrase structural distance between a gap and its filler.
(2) A structure’s complexity increases with the number of XP categories (S, VP, etc.) between a gap and the element with which it is associated. (O’Grady, 1997: 136)

As shown in Figure 1, ORs exhibit greater phrase-structural distance between gap and filler than SRs (3 XPs vs. 2 XPs), and this relatively greater distance is assumed to translate into a processing disadvantage (cf. O’Grady, to appear).

This second class of models therefore predicts a consistent processing advantage for SRs in both forward and backward filler-gap dependencies. This prediction is consistent with the SR processing advantage found in forward filler-gap dependencies in English and backward gap-filler dependencies in Japanese, Korean and some studies of Chinese—but not with the OR processing advantage reported in other studies of Chinese (Hsiao & Gibson, 2003; Y. Lin & Garnsey, 2007; Gibson & Wu, under revision; Qiao et al., submitted).

In sum, models based on linear/temporal distance predict that SRs will be more difficult to process in Korean, while models based on grammatical relations and/or phrase structure representations predict that Korean ORs will be more difficult.
1.4 Previous ERP studies of filler-gap dependencies

Thus far we have discussed filler-gap dependencies only in relative clauses (3). However, filler-gap dependencies are also found in other constructions such as *wh*-questions (4) and scrambling constructions in German, Japanese and Korean (5).

(3) \([\text{RC} \text{ the reporter}_i \text{ [who the senator attacked } _, \text{ ]}] \text{ admitted the error.}\)

(4) Which reporter\(_i\) did the senator attack \(\_\_\_\) ?

(5) \(\text{reporter}_i \text{-ACC senator-NOM } \_\_\_\) attacked

‘The senator attacked the reporter’

Forward filler-gap dependencies with object fillers like these consistently cause additional processing difficulty, as indexed by (a) slow anterior negative brain potentials between filler and gap, and (b) transient left anterior negativity (LAN) and/or P600 responses around gap positions (*relative clauses*: King & Kutas, 1995; Weckerly & Kutas, 1999; Müller, King, & Kutas, 1997; Münte, Schwirtz, Wieringa, Matzke, & Johannes, 1997; Vos, Gunter, Kolk, & Mulder, 2001; *wh-questions*: Kluender & Kutas, 1993a, 1993b; Kluender & Münte, 1998; Kaan, Harris, Gibson, & Holcomb, 2000; Fiebach, Schlesewsky, & Friederici, 2002; Felser, Clahsen, & Münte, 2003; Phillips, Kazanina, & Abada, 2005; Gouvea, Phillips, Kazanina, Poeppel, 2010; *scrambling constructions*: Rösler, Pechmann, Streb, Röder, & Hennighausen, 1998; Matzke, Mai, Nager, Rüsseler, & Münte, 2002; Schlesewsky, Bornkessel, & Frisch, 2003; Ueno & Kluender, 2003; Hagiwara, Soshi, Ishihara, & Imanaka, 2007).
Slow anterior negative brain potentials have been interpreted as indexing higher working memory costs for ORs (3) than for SRs. For example, in post-nominal SRs (example (1a) in Table 1), the head noun ‘reporter’ is immediately assigned a thematic role from the embedded verb, allowing simultaneous identification of the grammatical function of the head noun within the relative clause. In post-nominal ORs (example (1b) in Table 1), on the other hand, the head noun ‘reporter’ needs to be stored in working memory without a thematic role or grammatical function until the gap position is reached, which constitutes an additional burden on the working memory system (Gibson, 1990). The slow anterior negativity in response to forward filler-gap dependencies within the relative clause regions of ORs is purported to be an index of this cost (King & Kutas, 1995).11

Transient LAN responses to the main clause verb position (i.e., immediately following the gap position) in post-nominal ORs have instead been taken to index higher processing costs of associating gaps with their fillers. In SRs (example (1a) in Table 1), thematic role assignment by the embedded (‘attacked’) and main (‘admitted’) clause verbs occurs at different points in sentence processing (embedded verb: early relative clause region; main verb: right after the relative clause region), while in ORs (example (1b) in Table 1), the head noun receives thematic roles from the embedded (‘attacked’) and main (‘admitted’) verbs at approximately the same time (embedded verb: at the end of relative clause region; main verb: immediately after the relative clause region), resulting in a greater number of simultaneous long-distance computational operations in ORs at that position. Greater amplitude transient LAN is taken to be an index of this cost (Kluender & Kutas, 1993a, 1993b; King & Kutas, 1995).
P600s have been elicited around the gap positions of forward filler-gap dependencies in *wh*-questions (Kaan et al., 2000; Fiebach et al., 2002; Felser et al., 2003; Phillips et al., 2005; Gouvea et al., 2010) and in Japanese scrambling contexts (Ueno & Kluender, 2003; Hagiwara et al. 2007), sometimes in combination with phasic LAN responses. Kaan et al. (2000) argued that the P600 in response to gap positions is an index of syntactic integration (see also Fiebach et al., 2002; Phillips et al., 2005).

Reading time studies of Japanese (Kanno & Nakamura, 2001; Miyamoto & Nakamura, 2003; Ishizuka et al., 2003) and Korean (Kwon, 2008b; Kwon et al., 2010) relative clauses show the same slowed reading times to ORs that have been reported in head-initial languages like English with forward filler-gap dependencies. What remains to be determined is whether the same cognitive/neural mechanisms underlie the subject preference in both forward filler-gap dependencies (relative clauses and *wh*-questions in English, German, and Dutch, and scrambling in German, Japanese, and Korean) and backward gap-filler dependencies (relative clauses in Japanese and Korean). We also wanted to investigate the extent to which parametric variation across the East Asian languages (section 1.2) might affect brain responses.

Thus far there have been two ERP studies of backward gap-filler dependencies in pre-nominal relative clauses in East Asian languages: Japanese (Ueno & Garnsey, 2008) and Chinese (Yang, Perfetti, & Liu, 2010). Ueno & Garnsey (2008) observed ERP effects that were remarkably similar to those found in forward filler-gap dependencies: when compared to SRs similar to (3a) in Table 1, Japanese ORs similar to (3b) in Table 1 elicited (bilateral) anterior negativity from the onset of the embedded verb (‘attacked’), where it was significant, through the head noun position (‘reporter’), where it was
marginal. Ueno & Garnsey interpreted this response as indexing higher working memory demands related to structural distance (O’Grady, 1997). Additionally, there was a slow positive-going potential to ORs ((3b) in Table 1) with a centro-posterior maximum starting ~500 ms after the head noun (‘reporter’) and persisting across the rest of the sentence. Although this positivity differed substantially from the standard P600 in its morphology and time course, Ueno and Garnsey argued that it indexed syntactic integration difficulty in ORs due to the greater phrase structural complexity of ORs compared to SRs (O’Grady, 1997).

The design of the materials in the Yang et al. (2010) ERP study of Chinese relative clauses was different enough that the effects within the relative clause region are not comparable. However, at the head noun position there was again a sustained central-frontal negativity in response to ORs ((4b) in Table 1) compared to SRs ((4a) in Table 1), albeit with no subsequent late positivity.

Based on these previous ERPs studies, we can make the following predictions for brain responses to relative clauses in Korean.

2 Experiment

2.1 Predictions

Whether a dependency has filler-gap or gap-filler ordering, a successful parse depends on appropriate and timely association of the two dependent elements. To make predictions about the processing of backward gap-filler dependencies, a reasonable starting point is applying what we know about the processing of forward filler-gap
dependencies (6 & 7) to the surface word order regularities of backward gap-filler dependencies (8 & 9).

(6) Processes involved in forward filler-gap dependencies
(a) A filler (or incomplete dependency) needs to be maintained in working memory in anticipation of a gap.
(b) At the gap site, the parser needs to search through working memory for an appropriate filler to associate with the gap.
(c) The filler needs to be integrated with the gap.

(7) Neuro/cognitive indices of processing forward dependencies
(a) Maintaining a filler in working memory elicits a sustained anterior negativity, often (but not always) left-lateralized (King & Kutas, 1995; Fiebach et al., 2002; Felser et al., 2003; Ueno & Kluender, 2003; Phillips et al., 2005; Hagiwara et al, 2007).
(b) The backward search through working memory for a filler to associate with the gap seems to be indexed by a transient, typically left lateralized anterior negativity (LAN) (Kluender & Kutas, 1993a, 1993b; King & Kutas, 1995; Ueno & Kluender, 2003).
(c) Filler-gap integration at the gap site has been claimed to be indexed by a late positivity (Kaan et al., 2000; Fiebach et al., 2002; Felser et al., 2003; Ueno & Kluender, 2003; Phillips et al., 2005; Hagiwara et al, 2007).
(8) Hypothesized processes involved in backward gap-filler dependencies
(a) A gap (lack of a required argument of the embedded verb) needs to be maintained in working memory to complete the dependency.
(b) At the filler site, the parser needs to search backward through working memory for an appropriate gap to associate with the filler.
(c) The gap needs to be integrated with the filler.

(9) Hypothesized neuro/cognitive indices of processing backward dependencies
(a) Maintaining a gap in working memory might elicit a sustained anterior negativity.
(b) The backward search through working memory for a gap to associate with the filler might elicit phasic left-lateralized anterior negativity (LAN).
(c) Gap-filler integration at the filler site might be indexed by a late positivity.

On the assumption that such a processing account is on the right track, the question arises whether each of the analogous processes in forward filler-gap (6) and backward gap-filler dependencies (8) will elicit a similar brain response (9). In processing models based on the linear/temporal distance of an incomplete dependency, we might predict a larger ERP response to SRs than to ORs if maintaining a gap in working memory incurs a processing cost, as the linear distance between gap and filler is longer in SRs ((5a) in Table 1) than in ORs ((5b in Table 1).

However, it seems unlikely to us that there would be ERP effects associated with additional working memory requirements for maintaining a gap in working memory in a backward gap-filler dependency as there are for maintaining a filler in working memory
in English and other West Germanic languages. First, unlike forward filler-gap dependencies, in which a filler reliably signals the presence of a gap (*Active filler hypothesis*: Frazier & Clifton, 1989), in backward gap-filler dependencies in Korean (and likely in Chinese and Japanese as well), a gap does not reliably indicate the presence of a filler. Because Korean liberally drops both subject and object arguments (Kim, 2000), when the parser encounters a missing argument in Korean, it has no reason to assume that this will turn out to be a syntactic gap in a relative clause construction; this would not be the only or even the most likely continuation of the sentence. That is, a sentence fragment with a missing argument (10) could turn out to be a simple clause (11), a sentential complement clause (12) with a dropped argument, or part of a relative clause (13). Alternatively, it could even turn out to be a scrambled sentence without any missing argument (14). Note that the use of the adnominal marker (-ADN) is not even exclusive to relative clauses, as shown in (12): here it is used to mark the sentential complement of the head noun ‘fact’.

(10) Structural ambiguity of a gap

[ __ Yenghuy-lul hakkyo-eyse… ]

Y-ACC school-at…

(11) Argument drop in a simple clause

[ __ Yenghuy-lul hakkyo-eyse manna-ss-ta]

Y-ACC school-at meet-PST-DECL

‘(Someone) met Yenghuy at school.’
(12) Argument drop in a sentential complement clause

[ __ Yenghuy-lul hakkyo-eyse manna-n] sasil
Y-ACC school-at meet-ADN fact
‘the fact that (someone) met Yenghuy at school’

(13) Subject relative clause

[ __ i Yenghuy-lul hakkyo-eyse manna-n] sensayngnim_i
Y-ACC school-at meet-ADN teacher
‘the teacher who met Yenghuy at school’

(14) Scrambled sentence

[ Yenghuy-lul hakkyo-eyse sensayngnim-i manna-ss-ta]
Y-ACC school-at teacher-NOM meet-PST-DECL
‘The teacher met Yenghuy at school.’

Second, even if we were to assume that a gap could reliably indicate the presence of a filler, maintaining a gap is not likely to burden working memory. In forward filler-gap dependencies, maintaining a filler in working memory has been assumed to be difficult because storing an NP without a thematic role (or an incomplete dependency) imposes a WM burden (Gibson, 1990). In a gap-filler dependency, however, a gap is a gap, with no phonetic or thematic content to store. Although the parser might store the missing thematic role of a relative clause verb or the event that it represents with a missing argument instead of a “gap” per se in WM, relative clause verbs occur immediately before the head noun in both subject and object relatives in Korean. We therefore predict that the relative clause region in a Korean relative clause construction will not elicit analogous ERP effects (i.e., sustained anterior negativity) to those elicited by English relative clause filler-gap constructions.
The filler-gap processing requirements outlined in (6b&c) and (8), on the other hand, might be expected to cause similar processing difficulties in both forward filler-gap and backward gap-filler dependencies, despite ordering differences. A previous reading time study of Korean backward gap-filler dependences showed significantly longer reading times in ORs than in SRs, and this effect was most evident at the head noun position, where the parser has to search backward for an appropriate syntactic gap to associate with the filler (Kwon, 2008b; Kwon et al., 2010). Likewise, in English forward filler-gap dependencies, there is greater processing difficulty in ORs than in SRs at the main verb position, where the parser has to search backward for an appropriate filler to associate with the gap (King & Just, 1991; King & Kutas, 1995, among others). Accordingly, we predict phasic (left) anterior negativity and/or late positivity in response to ORs at the head noun position, similar to the responses to the backward search for the relevant filler (phasic LAN) and the integration of filler and gap (P600) in a forward filler-gap dependency. Moreover, any elicited late positivity may last throughout the sentence as it did in Ueno and Garnsey (2008), as schematized in Table 3.

INSERT TABLE 3 ABOUT HERE

2.2 Methods

2.2.1 Materials

For the ERP experiment, 80 sets of subject (15) and object (16) relative clauses with possessive head nouns were constructed.¹³,¹⁴
A norming study was conducted to control for the naturalness of SRs and ORs, following Miyamoto and Nakamura (2003). This was done to ensure that the naturalness of the events denoted in the experimental sentences would not bias one interpretation over the other. 144 native Korean speakers living in Korea participated in the norming study. Sentences were created by replacing the gap with its associated head noun in each of eight sets of SR and OR conditions. For example, for SRs (15) and ORs (16), sentences like (17) and (18) were created.

(17) Norming sentence generated from SR condition
uywon-i sinmwunsya-uy sacang-ul pimilliey cengchickeulo iyonghaya-ns
senator-GEN newspaper-GEN publisher-ACC secretly politically exploit-ADN
‘The senator secretly took advantage of the publisher of the newspaper for political purposes.’
A norming study for another experiment with two long-distance dependency conditions was included in the same experimental paradigm. The norming sentences were split into four lists using a Latin-square design. Participants saw one sentence from each SR and OR pair, (e.g., (17) or (18)), and rated the naturalness of each sentence (1 if it sounded natural and 5 if it sounded strange). Three subjects did not complete the questionnaire and thus were excluded from the analysis. The means for plausibility were 2.5 for the sentences formed from SRs and 2.6 for the sentences formed from ORs. A student’s t-test showed that this difference was not significant [$t(140) = 2.59, p < .1$].

The ERP study was run concurrently with another in the same experimental paradigm. Thus, 80 further sets of object relatives with different head noun types (‘The painter who the representative of the gallery evaluated highly at the international exhibition gained the attention of the world.’) and adjunct clause minimal pair sentences with dropped object arguments (‘Because the representative of the gallery evaluated (him,) highly at the international exhibition, the painter, gained the attention of the world.’) were added (i.e., the other two long-distance dependency conditions – one syntactic and the other referential – included in the norming study). Moreover, since at the time of the study there were no previously reported ERP results available for Korean to which our experimental results could be compared, another 210 sets of filler sentences were included to elicit standard N400, P600, and LAN effects. These filler sentences
consisted of 70 sets each of phrase structure violations of headedness (the use of prepositions instead of postpositions, which are required by the rigidly head-final structure of Korean) (19), semantic incongruity violations (20), and so-called “scrambled” sentences in which a direct object was fronted to the beginning of the sentence (21).^16

(19) Phrase structure violations

(a) Grammatical control
emma-ka ocen-ey kongwon-ulo sanchayk-ul ka-si-ess-ta
Mom-NOM morning-at the.park-to walk-ACC go-HON-PST-DECL
‘Mom went to the park for a walk.’

(b) Ungrammatical sentence: headedness violation
emma-ka ocen-ey ulo-kongwon sanchayk-ul ka-si-ess-ta
Mom-NOM morning-at to-the.park walk-ACC go-HON-PST-DECL
‘*Mom went the park to for a walk.’

(20) Semantic incongruity violations

(a) Congruous control
achim-ey salamtul-i pa p-ul mek-ess-ta
morning-in people-NOM rice-ACC eat-PST-DECL
‘In the morning, people ate a meal.’

(b) Incongruous sentence
achim-ey salamtul-i chayk-ul mek-ess-ta
morning-in people-NOM book-ACC eat-PST-DECL
‘#In the morning, people ate a book.’
(21) Scrambling

(a) in situ control
ku yuchiwon-uy woncang-i hakwon-uy nyencwung hayngsa-ey
that kindergarten-GEN principal-NOM school-GEN annual event-to

hakpwumotul-ul chotayhay-ss-ta
parents-ACC invite-PST-DECL
‘The principal of the kindergarten invited the parents to the annual school event.’

(b) Scrambled sentence
hakpwumotul-ul ku yuchiwon-uy woncang-i hakwon-uy
parents-ACC that kindergarten-GEN principal-NOM school-GEN

nyencwung hayngsa-ey ___ chotayhay-ss-ta
annual event-to invite-PST-DECL
‘~The parents, the principal of the kindergarten invited __ to the annual school event.’

All experimental and filler sentences were split into two lists of 370 sentences each using a Latin square design. These were further divided into twelve sub-lists, of which ten contained thirty-one sentences and the remaining two contained thirty sentences. The sentences in each list were pseudo-randomized, such that sentences from the same condition never appeared consecutively. In addition, the stimuli were presented in a different random order for every participant to prevent order-related effects.

2.2.2 Participants

Twenty-two native Korean speakers were paid $10/hour for their participation in the ERP study (female = 14, male = 8). At the time of the experiment, all participants were between the ages of 22 and 31 (mean: 25) and were enrolled in graduate school or in English classes at UCSD Extension. The average length of stay in the U.S. was 13 months (range of length of stay: 2 months to 3.5 years). All participants were right-handed with no neurological disorders and normal or corrected-to-normal vision.
2.2.3 Procedures

Participants were run in a single session lasting about 2.5 hours, including preparation. Sentences were presented visually in Korean *Hangul* (phonetic) script in the center of a monitor screen, one *ejel* (a writing unit typically composed of one free morpheme with additional dependent morpheme(s), e.g., ‘singer-NOM’) at a time. Each *ejel* was presented for 300 ms with a 500 ms stimulus onset asynchrony (SOA). The interstimulus interval between sentences was 3000 ms and subjects were given as much rest as they wished between sets of lists. Yes/No comprehension questions were presented at the end of every five sentences on average to maintain participants’ attention. The comprehension questions focused on the content of the immediately preceding sentence. For example, the comprehension question (22) immediately followed the experimental sentence (15).

(22) Question

sinmwunsu-uy sacang-iy uyon-ul cengchicekulo iyonghaysssupnikka?
newspaper-GEN publisher-NOM senator-ACC politically exploited?
‘Did the publisher of the newspaper take advantage of the senator?’

Each comprehension question appeared 1000 ms after the offset of the sentence-final word and remained on the screen until participants responded by pressing hand-held buttons. The response hand was counterbalanced to control for dominance. The next sentence started 2000 ms after the response. There was a practice session with seven sentences before the experiment.
2.2.4 Electrophysiological Recording

The electroencephalogram (EEG) was recorded from 26 tin electrodes mounted geodesically in an electro-cap. These sites included midline prefrontal (MiPf), left and right lateral prefrontal (LLPf and RLPf), left and right medial prefrontal (LMPf and RMPf), left and right lateral frontal (LLFr and RLFr), left and right medial frontal (LMFr and RMFr), left and right medial lateral frontal (LDFr and RDFr), left and right medial central (LMCe and RMCe), midline central (MiCe), left and right medial lateral central (LDCe and RDCe), left and right lateral temporal (LLTe and RLTc), left and right medial lateral parietal (LDPa and RDPa), midline parietal (MiPa), left and right lateral occipital (LLOC and RLOC), left and right medial occipital (LMOc and RMOc), and midline occipital (MiOc). Each electrode was referenced online to the reference electrode on the left mastoid. To monitor blinks and eye movements, electrodes were placed on the outer canthi and under each eye, and were referenced to the left mastoid. Impedances were kept below 5KΩ. The EEG was amplified with Nicolet amplifiers, digitized at a sampling rate of 250 Hz.

2.2.5 Data Analysis

For phasic effects, measurements were taken of single-word ERP averages, which consisted of 1000 ms epochs, including a 100 ms prestimulus baseline. For longer-lasting effects, measurements were taken of two-word averages, which consisted of 1700 ms epochs (2 x 500 ms SOA, a 400 ms prestimulus baseline, and the first 300 ms of the following [third] word). Trials contaminated by excessive muscle activity, amplifier blocking, or eye movements were discarded offline before averaging. On average, 4%
and 9% of trials were rejected for single- and two-word averages, respectively. The averaged data were algebraically re-referenced to the mean of the activity at the two mastoids. For purposes of visualization only, ERP waves were smoothed using a low pass filter with a cutoff frequency of 5 Hz.

The data were submitted to a full analysis – i.e., an overall ANOVA with repeated measures of experimental condition (SR vs. OR) and electrodes (26 levels). In addition, a distributional analysis was conducted, including experimental condition (SR vs. OR), hemisphere (left vs. right), laterality (lateral vs. medial) and anteriority (four levels: prefrontal vs. frontal vs. parietal vs. occipital) as factors. Electrodes included were left and right lateral prefrontal (LLPf and RLPf), left and right medial prefrontal (LMPf and RMPf), left and right lateral frontal (LLFr and RLFr), left and right medial frontal (LDFr and RDFr), left and right lateral temporal (LLTe and RLTe), left and right medial lateral parietal (LDPa and RDPa), left and right lateral occipital (LLOc and RLOc), and left and right medial occipital (LMOc and RMOc). When it was necessary to corroborate smaller local effects, an ANOVA was performed on quadrant regions of electrodes (left frontal: LLPf, LLFr, LMPf, LDFr; right frontal: RLPf, RLFr, RMPf, RDFr; left posterior: LLTe, LLOc.; LDPa, LMOc; right posterior: RLTe, RLOc, RDPa, RMOc). All analyses were run on mean amplitudes of specified latency intervals (N100: 80–120 ms; P200: 150–250 ms; P600: 500–800 ms; N400: 300–600 ms; phasic LAN: 300–600 ms; sustained anterior negativity: 300–1100 ms) unless otherwise noted. The Huynh-Feldt (1976) correction for lack of sphericity was applied, and corrected $p$-values are reported with the original degrees of freedom.
2.3 Results

The mean correct response rates to comprehension questions following SRs (15) and ORs (16) did not differ significantly: 70% vs. 68%, respectively. Comprehension accuracy was higher for filler sentences: 94% for sentences with and without phrase structural violations (19), 95% for sentences with and without semantic incongruity (20), and 85% for sentences with and without scrambling (21).19

Recall that the focus of this experiment was the processing of backward (gap-filler) dependencies in Korean relative clauses; the results were then to be compared with the processing of forward dependencies in English relative clauses. To investigate the effects on the ERP record of an unfilled gap in need of integration with a subsequent filler, we planned to examine ERP responses to SRs and ORs in three regions: relative clause, head noun and main verb regions, as shown in Table 3. Before presenting the main experimental findings with regard to relative clauses, however, we first present the results of the filler sentences, which help to provide some context for the interpretation of the experimental results.

2.3.1 Filler Sentences

2.3.1.1 Late Positivity

The ungrammatical filler sentences with prepositions in place of postpositions (‘*to-the.park’) (19b) elicited a positive-going ERP in comparison to the grammatical controls with postpositions (‘the.park-to’) (19a). This effect was widely distributed across the scalp (Figure 2). The full ANOVA in the 500–800 ms latency range with all 26 electrodes showed a main effect of grammaticality [F(1,21) = 20.32, p < .0002] caused by
a pronounced positivity to the ungrammatical compared to the grammatical condition. In the distributional analysis, there was again a significant main effect of grammaticality \( F(1,21) = 21.66 \ p < .0001 \) and also a significant interaction of grammaticality, laterality, and anteriority \( F(3,63) = 9.58 \ p < .0004 \) due to greater positivity to the ungrammatical condition, particularly over the medial posterior region (see Figure 2B).

INSERT FIGURE 2 ABOUT HERE

2.3.1.2 N400

The semantically incongruous filler sentences (20b) (e.g., ‘In the morning, people ate a book’) elicited a negative-going ERP in comparison to the congruous controls (20a) (e.g., ‘In the morning, people ate a meal’; see Figure 3). The full ANOVA in the 300–600 ms latency range with all 26 electrodes showed a main effect of congruity \( F(1,21) = 5.21, \ p < .003 \) and a significant interaction of relative clause type and electrodes \( F(25,525) = 5.58, \ p < .0001 \). In the distributional analysis, there was again a main effect of congruity \( F(1,21) = 4.52, \ p < .0045 \), a significant interaction of congruity and laterality \( F(1,21) = 6.81, \ p < .016 \), and an interaction of congruity and anteriority \( F(3,63) = 10.94, \ p < .0024 \), as this effect was observable across the scalp, but had its maximum at central and parietal midline electrodes (see Figure 3C). On visual inspection, the difference looked slightly larger over the right than over the left side of the head, and this impression was confirmed by a interaction of congruity and hemisphere \( F(1,21) = 5.63, \ p < .027 \). Overall, this response had the latency, morphology, and scalp distribution typical of an N400 effect.

INSERT FIGURE 3 ABOUT HERE
2.3.1.3 LAN

Scrambled sentences (21b) elicited more negativity relative to unscrambled sentences (21a) starting approximately 300 ms post stimulus onset of the subject NP-NOM (Figure 4). On visual inspection, the negativity showed a symmetrical anterior maximum. This impression was confirmed by a significant main effect of scrambling in the full ANOVA \[F(1,21) = 7.09, p < 0.014\] and distributional analysis \[F(1, 21) = 6.5, p < 0.018\] in the 300 to 1100 ms latency range. In the distributional analysis in the same latency range, there was a marginal interaction of scrambling and laterality \[F(1,21) = 3.84, p < 0.06\] due to the larger difference over anterior medial regions (Figure 4C). There was also a marginal interaction of scrambling, hemisphere, and laterality \[F(1,21) = 4.01, p < 0.058\] in the distributional analysis. This was likely due to the overall larger differences at medial compared to lateral electrodes, which in turn showed more extensive differences over the right than over the left side of the head (see Figure 4C).

INSERT FIGURE 4 ABOUT HERE

There were somewhat surprisingly no subsequent ERP differences – neither a phasic LAN nor a late positive response – to the words immediately preceding (hayngsaye, ‘event-to’) and following (chotayhay-ss-ta, ‘invite-PST-DECL,’ i.e. the sentence-final main clause verb) the purported gap position in scrambled sentences (21b).

2.3.2 ERP Results for SR and OR Sentences

As an illustration, Figure 5 shows the ERP responses elicited at a left frontal electrode by ORs vs. SRs in the sentence-initial relative clause region of the stimulus
materials (including the head noun, the last word of the average). Visual inspection suggests that ORs elicited greater negativity than SRs at two sentence positions: the second and third words of the pre-nominal relative clause (‘publisher-NOM secretly’; see Table 3), and again at the head noun (‘senator-GEN’). Each of these effects is discussed in detail in what follows using ERP responses obtained over the entire head.

INSERT FIGURE 5 ABOUT HERE

2.3.2.1 Relative clause region prior to the relative clause verb

Recall the structure of the relative clause (Table 3): W1 was always a noun in the genitive, associated with W2, which appeared in the nominative if the relative clause gap was the object (OR) and in the accusative if the gap was the subject (SR). Visual inspection of the data to the W2 position (see Table 3) revealed a larger broad frontal negativity to the OR (‘publisher-NOM’) (16) compared to the SR (‘publisher-ACC’) condition (15), particularly at lateral electrodes. This effect continued throughout the response to W3, ‘secretly’, as shown in Figure 6.

INSERT FIGURE 6 ABOUT HERE

To corroborate apparent early effects (Figure 6B), mean voltage measures were taken in the N100 (80 to 120 ms) and P200 (150 to 250 ms) latency windows. These measures were subjected to both full and distributional omnibus ANOVAs. In the analysis of the 80 to 120 ms interval, there was no significant effect either in the full analysis (relative clause type x 26 electrodes) \[F(1,21) = 1.23, p < .3\] or in the
distributional analysis (relative clause type x hemisphere x laterality x anteriority) (all Fs < 2.5). On the other hand, in the omnibus ANOVA of the 150 to 250 ms interval (i.e., with regard to apparent P200 effects), there was a significant main effect of relative clause type both in the full analysis \([F(1,21) = 5.14, p < .04]\) and in the distributional analysis \([F(1,21) = 5.83, p < .03]\), indicating that the OR condition began to elicit early negativity over much of the scalp.

Additionally, to quantify later effects, an analysis was conducted in the time window of 300 to 1100 ms, from the second half of the NP ‘publisher-NOM/ACC’ to 100 ms after the onset of ‘politically’. In the full analysis, there was a significant interaction of relative clause type and electrode \([F(25,525) = 3.05, p < .001]\), and in the distributional analysis, there was a significant interaction of relative clause type and anteriority \([F(3,63) = 5.16, p < .03]\). This was due to more pronounced negativity in response to ORs over anterior regions of scalp (Figure 6C).

These effects indicate that ORs elicited more anterior negativity than SRs. Significant effects in the P200 time window indicate that this negativity in response to ORs tended to onset early (~200ms); significant interactions in the later time window of 300 to 1100 ms indicated that the negativity became more frontally distributed in this later time window.

### 2.3.2.2 Relative clause at the relative clause verb and the head noun region

Visual inspection of the waveforms suggested fairly widespread negativity in response to the head noun of the OR condition (16) compared to the head noun of the SR condition (15), and at some (especially right posterior) electrodes, less consistent negativity in response to the relative clause verb of the OR condition as well (Figure 7).
To compare these results directly to those of Ueno & Garnsey (2008), an analysis was first conducted on the ERPs to the relative clause verb and the head noun positions together. In the time window of 300 to 1100 ms post-stimulus onset of the relative clause verb ‘exploit-ADN’, spanning the second half of the relative clause verb to 100 ms after the onset of W7 in Table 3 ‘office-to’, there was a main effect of relative clause type in the full analysis \([F(1,21) = 5.22, p < 0.0328]\) and in the distributional analysis \([F(1,21) = 5.72, p < 0.0262]\). There were no other significant effects (all Fs < 1.2).

While there was in general more negativity to the relative clause verb and head noun positions in the OR condition, as there had been in Ueno & Garnsey’s (2008) study of Japanese relative clauses, the ERP responses to these two sentence positions showed different distributions, suggesting that they are distinct. As noted previously, the negativity to the relative clause verb appeared to have a right posterior maximum (Figure 7C), while the negativity to the head noun was widely distributed over the scalp and more pronounced at frontal sites (Figure 7D). Moreover, over left frontal regions of scalp, the response to the relative clause verb in the OR condition was in fact positive in polarity (Figures 7B & 7C).

Thus separate statistical analyses were undertaken of these two apparently separate effects. In a latency window of 300 to 600 ms post-stimulus onset of the relative clause verb, there was no significant effect in the full analysis (all Fs < 1) but a marginal main effect of relative clause type in the distributional analysis \([F(1,21) = 3.37, p < .08]\),
reflecting overall more negativity to the relative clause verb in the OR (0.3062 µV) than in the SR condition (0.648 µV) (Figure 7C). However, quadrant analyses in the same latency window revealed a marginal main effect of relative clause type only in the left frontal region \[F(1,21) = 4.08, p < 0.0563\], where the response was actually more positive to the relative clause verb in the OR than in the SR condition. There were no significant effects in the other regions (left posterior: \[F(1,21) = 0.61, \text{n.s.}\]; right frontal: \[F(1,21) = 0.06, \text{n.s.}\]; right posterior: \[F(1,21) = 0.88, \text{n.s.}\]).

In a latency window of 800 to 1100 ms post-stimulus onset of the relative clause verb ‘exploit-ADN’ (i.e., 300 to 600 ms post-stimulus onset of the head noun ‘senator-GEN’), there were significant main effects of relative clause type in both the full \[F(1,21) = 8.36, p < .01\] and distributional analyses \[F(1,21) = 8.87, p < .01\]), as well as a marginal interaction of relative clause type, hemisphere, laterality and anteriority \[F(3,63) = 2.43, p < .075\] in the distributional analysis (see Figure 7D). This marginal four-way interaction was caused by stronger effects at right medial and left anterior lateral electrodes.\footnote{20} Other effects were non-significant (all Fs < 1).

However, when ERPs were rebaselined at the onset of the head noun (‘senator-GEN’) position (Figure 8), there were surprisingly no significant effects of relative clause type in a latency window of 300 and 600 ms, either in the full analysis \[F(1,21) = 1.93, p < .18\] or in the distributional analysis \[F(1,21) = 2.33, p < .14\). There was, however, a significant effect of relative clause type in the left frontal region of the quadrant analysis \[F(1,21) = 5.92, p < 0.024\], and no significant effects in other quadrants (all Fs < 1.5).
2.3.2.3 Main clause verb region

There was no effect related to relative clause type in this region. SRs and ORs were not significantly different from each other in any time window.

3 Discussion

The goal of this study was to investigate to what extent the cognitive/neural processes underlying the processing of post-nominal relative clauses in more familiar languages like English, Dutch and German are similar to those underlying the processing of pre-nominal relative clauses in head-final languages like Korean. We also wanted to investigate the effect of parametric variation in consistent headedness (Japanese and Korean), case marking (Japanese and Korean), and relative clause marking (Chinese and Korean) across the East Asian languages. To address these questions, we also examined the processing of “baseline” linguistic manipulations, namely sentences that contained phrase structure violations, semantic incongruity violations, and “scrambled” constituents; these data were needed because at the time of the study, no electrophysiological research had previously been done on Korean. These three types of manipulations elicited standard P600, N400 and LAN responses, respectively, in comparison to control sentences with no syntactic violations, semantic violations, or scrambled constituents (i.e., with normal word order). The responses were similar to previously reported effects in their morphology, latency and distribution. This suggests that the ERP responses elicited in the processing of Korean sentences are no different from those observed in other languages.21
Overall, Korean relative clauses elicited ERP effects quite similar to those elicited by English relatives (King & Kutas, 1995). As in English, ORs compared to SRs elicited a negative potential with an anterior maximum to processing of the relative clause region – albeit for different reasons and independent of the processing of the filler-gap dependency, as will be discussed below. At the head noun position, Korean ORs again elicited a negative potential with an anterior maximum, an effect similar but not identical to equivalent comparisons in English (King & Kutas, 1995: phasic LAN effect) and Japanese relatives (Ueno & Garnsey, 2008: sustained negativity starting from the preceding RC verb and continuing through the following head noun). On the other hand, Korean ORs did not elicit a P600 or variant thereof at the region following the head noun, a finding different from that of Ueno and Garnsey. This set of results will be discussed in terms of the effects of major typological features – including pre- vs. post-nominal relative clauses and morphological marking – on parsing strategies.

3.1 Effects within the relative clause region prior to the embedded verb

Within the relative clause region, ORs (‘publisher-NOM’) (16) elicited a sustained anterior negativity in comparison to SRs (‘publisher-ACC’) (15). The distribution of slow potential effects has varied across studies (left anterior maximum: Kluender & Kutas, 1993a, 1993b; Kluender & Münte, 1998; Fiebach, et al., 2002; symmetrical anterior maximum: King & Kutas, 1995; Ueno & Kluender, 2003; Phillips et al., 2005; (slightly) right lateralized anterior-central maximum: Müller et al., 1997; Ueno & Kluender, 2009), though they are in general bilateral and, if lateralized, usually to the left. Thus, it seems that the slow potential effects elicited by ORs at the main argument of the relative clause (W2, ‘publisher-NOM’, see Table 1) have a latency and a scalp distribution compatible
with the slow anterior negativities reported in previous studies – as well as with the anterior negativity elicited to our scrambled sentences (Figure 4).

However, this effect within the relative clause regions is puzzling for several reasons. First, SRs (‘publisher-ACC’) (15) start with an apparently non-canonical sentence-initial NP-ACC, while ORs (16) start with NP-NOM, and thus present a seemingly canonical sentence beginning with the subject. Previous ERP experiments in German and Japanese have shown that scrambled sentences starting with non-canonical objects elicit a (L)AN or a widespread negativity in comparison to sentences starting with canonical subjects (Rösler et al., 1998; Matzke et al., 2002; Schlesewsky et al., 2003; Ueno & Kluender, 2003; Hagiwara et al., 2007), and the scrambling condition in our filler sentences replicated these results in Korean (Figure 4). In light of this, the slow potential with an anterior maximum in response to ORs with an initial NP-NOM seems surprising and in need of explanation.

Although one might speculate that this effect was related to the intrinsic difficulty associated with processing the filler-gap dependency in a relative clause, it is important to bear in mind that at W2, the structural cues that the current incoming clause forms part of a relative clause are not yet available. Moreover, given the presence of various types of filler sentences used in the current experiment, W2 NP-ACC or NP-NOM could have turned out to be part of a simple mono- or bi-clausal sentence. Given this, the ERP response to ORs (NP-NOM) is most likely related to processing difficulty associated with a nominative-marked NP, independent of the processing of a relative clause.

Processing difficulty has repeatedly been attested when there is a single nominative marked NP, as well as when there is a sequence of nominative marked NPs in
both Korean and Japanese (i.e., NP-NOM NP-NOM) (Korean: Kim, 1999; Kwon, 2008a; Japanese: Inoue, 1991; Miyamoto, 2002; Yamashita, 1997). That is, nominative-marked NPs seem to be more salient than NPs with other case markers (Miyamoto, 2002). While the source of this difficulty has not been clearly identified, we believe that the anterior negativity to NP-NOM in the present study is best accounted for in terms of the discourse function that is associated with the subject and the nominative marker. Since the remaining part of the sentence predicates over the subject (cf. Reinhart, 1982), successful processing of the subject-predication relation might require the subject to be more deeply encoded than other arguments.

On the other hand, subjects often serve as sentential topics (Langacker, 1991; Reinhart, 1982) that represent old information, and thus tend to be dropped. For example, in Korean, 70% of subjects are dropped (Kim, 2000). When they occur despite representing old information, they tend to be marked with a topic marker (Choi, 1997). Thus, when the subject does occur with a nominative marker, which typically encodes new information in Korean (Choi, 1997), it would alert the reader to pay extra attention to the subject, which could lead to extra working memory demands in ORs (NP-NOM) (for processing difficulty of complex subjects in English, see Kluender, 2004).

A further and related question is why there is no ERP effect corresponding to the sentence-initial non-canonical word order in SRs (NP-ACC), as was the case in response to our scrambled sentences (Figure 4). We don’t have a clear answer for this. One possibility is that the response to the NP-ACC may have been overridden by the response to the NP-NOM discussed above. Although a previous ERP study of Japanese backward gap-filler dependencies by Ueno and Garnsey (2008) did not show any effect in response
to either a sentence-initial NP-ACC (SR) or a sentence-initial NP-NOM (OR) within the RC region, in their study, the NP-ACC/NOM in SRs and ORs was immediately followed by the RC verb without intervening adverbial phrases (i.e., [RC NP-ACC/NOM Verb]). Note that in processing pre-nominal relative clauses, the argument structure of the RC verb is a crucial cue that the parser has to rely on to parse the missing argument. This is even more so the case for ORs (i.e., [RC NP-NOM Verb]) since they start with a canonical subject, and the argument structure of the relative clause verb is the first cue that the parser can use to recognize that there is a missing argument. Thus these additional processes at the following word (i.e., the relative clause verb) could have confounded the ERP results in Ueno and Garnsey (2008). In any case, further study will be required to determine the nature of this response to nominative-marked NPs (and the lack of response to the sentence-initial accusative-marked NP).

In summary, Korean object relative clauses elicited a bilateral continuous anterior negativity compared to SRs, remarkably similar to effects seen in English and in response to scrambled sentences in Korean. However, it should be noted that different cognitive processes underlie these related effects. The anterior negativity in response to English ORs and to Korean scrambled sentences is attributed to the processing difficulty of a filler-gap dependency: it is an index of costs associated with holding a filler (or incomplete dependency) in working memory. In contrast, the anterior negativity in Korean relative clauses is attributed to the processing difficulty associated with encoding the discourse function of a nominative-marked NP, independent of the processing of a filler-gap dependency in the relative clause.
3.2 Effects at the embedded verb and the head noun region

ORs (16) elicited significantly greater negativity in comparison to SRs (15) when measurements were taken across the relative clause verb and head noun positions together. When the ERP responses to the relative clause verb and to the head noun were measured separately within this two-word average, i.e. without rebaselining, the effect turned out to be stronger at the head noun position but considerably weaker and self-contradictory at the relative clause verb position: there was a marginal effect of negativity in the distributional analysis but curiously no effect in the right posterior quadrant, where it appeared maximal (Figures 7A & 7C), with a marginal effect of positivity in the left anterior quadrant instead. This suggested that the head noun position was driving the overall negative response at the end of the relative clause. Yet when we rebaselined at the head noun position itself (Figure 8), the effect persisted only in the left anterior quadrant analysis – though this could also have been an artifact of rebaselining, given the marginally significant left anterior positivity in the prior epoch. However, as this was a planned comparison at a sentence position where we had predicted a LAN effect (9b) and found significant evidence of it in three of the four ways in which we measured it, we conclude that this effect was reliable.

Moreover, the latency and distribution of this effect are compatible with the phasic (left) anterior negativities related to backward search at gap positions in ERP studies of forward filler-gap dependencies across languages (English: Kluender & Kutas, 1993a; King & Kutas, 1995; Dutch: Vos et al., 2001; German: Felser et al., 2003; Japanese: Ueno & Kluender, 2003). Thus despite differences in filler-gap ordering, backward gap-filler association in Korean relative clauses elicits phasic (L)AN responses
that are strikingly similar in nature to those elicited by forward filler-gap association cross-linguistically (see Section 3.4.2 for a comparison with Ueno & Garnsey’s (2008) study of Japanese).24

Consider how backward search might operate in a Korean gap-filler dependency, and how this process might result in differential working memory costs for ORs vs. SRs. Since the beginning of the dependency is not marked by a filler, there is no possibility of filler reactivation. However, in Korean, the adnominal marker -(nu)n attached to the embedded verb signals that the current clause serves as a modifier of (cf. (13)) or complement to (cf. (12)) the following noun. If the relationship is one of modification, at the head noun, the parser is compelled to posit a gap (or an incomplete dependency) and has to search backward through previously parsed material for an unfilled argument position in order to associate that gap with the newly available filler. Such gap-positing and backward search occurs both in SRs and ORs. However, locating this unfilled argument position in previously parsed material (or retrieving an incomplete syntactic representation of already parsed material for purposes of gap-filler association) could incur greater working memory costs in ORs than in SRs, for the following reasons.

Within the SR, the structural representation of the verb phrase is complete, as both the object and the verb (i.e., ‘publisher-ACC exploit-ADN’) have already entered the parse when the embedded verb position is encountered. Thus, in this case, semantic interpretation of the verb phrase is readily available, and at the head noun position the parser simply needs to establish the subject–predicate relation between the head noun and the relative clause. On the other hand, at the embedded verb position in ORs, the semantic interpretation of the verb phrase cannot be completed because the object is still
missing. Even when the head noun becomes available, its semantic relation with the relative clause is not so straightforward when compared to the subject-predicate relation in SRs. In ORs, the parser’s work proceeds in two steps: first, it has to associate the head noun with the missing argument inside the verb phrase. By doing so, it completes the semantic representation of the verb phrase, and only after that can it determine the overall subject-predicate relation within the relative clause by reactivating and attaching the relative clause subject. This extra step (associating the head noun with the missing argument inside the VP) may impose greater working memory costs, as indexed by a larger phasic LAN to ORs.

3.3 Implications for processing models

Here we discuss the implications of the SR vs. OR processing difference set out in section 3.2 from the following two perspectives: first in terms of incremental parsing and second in terms of the theoretical models presented in the Introduction.

The LAN in response to the head noun of ORs is overall compatible with incremental and predictive parsing (Sturt & Crocker, 1996; Yamashita, 1994; Miyamoto, 2002; Altman & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003; but see Pritchett, 1991, for a different view). Given the SOV word order of Korean, the non-canonical sentence-initial NP-ACC in SRs signals a missing subject (i.e., a gap) and a transitive structure, even before the arrival of the verb (cf. Kamide et al., 2003). In ORs, on the other hand, there are no comparable cues to the exact structural representation until the embedded verb position. The sentence-initial NP-NOM signals neither a missing argument (i.e., an object gap) nor a transitive structure. It is not until the embedded verb position that the parser recognizes a missing argument and postulates a transitive structure in ORs,
based on the argument structure of the verb. Consequently, gap-filler association at the head noun position could be more difficult in ORs than in SRs because of spillover effects from the preceding embedded verb position, as indexed by the LAN.

One problem with this hypothesis, however, is that there was no clear ERP effect associated with recognizing a missing argument and the projection of a transitive structure early within the relative clause in SRs or at the relative clause verb position in ORs. Although such responses in SRs could have been overridden by the response to the nominative-marked NP in ORs, as discussed in Section 3.1, the effect at the relative clause verb position in ORs was quite weak, suggesting such processes may not demand much in the way of resources at this point in the sentence. Then the crucial difference between SRs and ORs would be gap-filler association difficulty itself, as discussed below.

The processing advantage of SRs coincides with predictions of the accessibility hierarchy (Keenan & Comrie, 1977) and the phrase-structural distance hypothesis (O’Grady, 1997). Object gaps rank lower than subject gaps in the accessibility hierarchy and are more deeply embedded in the phrase-structural representation than subject gaps, as shown in (1) and Figure 1, respectively. Although these two hypotheses are based on different approaches to the study of language (the accessibility hierarchy treats grammatical relations as primitives decoupled from particular syntactic structures; O’Grady’s theory relies on the standard phrase-structural representation of grammatical relations adopted in generative grammars), it has recently been suggested that the accessibility hierarchy correlates with the total number of phrase structure nodes of possible derivations (the entropy reduction hypothesis: Hale, 2006). In this approach,
initial parsing decisions are influenced both by the overall frequency of occurrence of SRs vs. ORs within the language, as well as by the degree of temporal structural ambiguity (Hale, 2006). Based on language-specific frequency (English: Roland, Dick & Elman, 2007; Korean: Kwon, 2008b; Yun, Hale, & Whitman, 2010; cf. Fox 1987) and transitional structural ambiguity in on-line parsing, this model accounts for the SR processing advantage both in English (Hale, 2006) and in Korean (Yun et al., 2010). That is, in this approach, the accessibility hierarchy is accounted for in terms of phrase structural complexity weighted by frequency. This means that both the accessibility hierarchy and the phrase-structural distance hypothesis could be defined in terms of the complexity of a syntactic tree, suggesting that processing difficulty may arise from the complexity of the mental representation of structure.

These interpretations suggest that similar ERP effects in the main clause region in Korean (i.e., at the head noun) and English (i.e., at the main verb) could indeed be for similar reasons: in both English and Korean, filler-gap (or gap-filler) association may consume more working memory resources when the structural representation of a gap is more complex.

3.4 Language universals and universal parsing strategies

In the introduction to this paper, we discussed the potential effects of typological variation in word order on sentence processing, mainly focusing on processing requirements involved in pre- vs. post-nominal relative clauses in VO and head-final OV languages. We also discussed major morphological differences in Japanese, Korean and Chinese: the marking of noun phrases in Korean and Japanese and of the right edge of relative clauses in Chinese and Korean. Below we discuss the implications of these cross-
linguistic differences on our findings. We first discuss the processing strategies of long-distance dependencies in reference to typological variation in word order (i.e., pre- vs. post-nominal relative clauses) before we compare ERP results from three relative clause studies in East-Asian languages with pre-nominal relative clauses: Korean (present study), Japanese (Ueno & Garnsey, 2008) and Chinese (Yang, et al., 2010).

3.4.1 Typological variation in word order and its effect on processing strategies

Here we compare experimental results from the processing of backward gap-filler dependencies in Korean relative clauses with results from the processing of forward filler-gap dependencies (head-initial relative clauses, *wh*-questions, and scrambling) in previous studies. In doing so, we come to the conclusion that backward gap-filler dependencies exhibit only one cognitive process in common with forward filler-gap dependencies.

Recall that three processes were initially hypothesized to be involved in backward gap-filler dependencies (8). By analogy to the processing of forward filler-gap dependencies, it was predicted that (i) a sustained anterior negativity would be elicited within the relative clause due to holding a gap in working memory, (ii) a phasic LAN effect indexing a backward search through working memory for a gap to associate with the filler would be elicited at the head noun position, and (iii) late positivity would be elicited at the head noun position indexing filler-gap integration. Of all these predictions, only (ii) was confirmed: a phasic LAN but no late positivity was elicited at the head noun position, and there was no sustained anterior negativity indexing storage of a gap in working memory.
For backward gap-filler dependencies, the apparent lack of processing difficulty associated with storage of a gap in working memory is perhaps not so surprising, insofar as the gap does not carry any phonetic or thematic information. That is, a gap in a backward dependency is simply a silent place-holder in the structural representation: thematic information about the gap comes from the relative clause verb, which occurs right before the head noun position, and referential information comes from the head noun itself. This is different from forward filler-gap dependencies, in which holding a filler in working memory as a phonological and/or semantic unit devoid of thematic and grammatical relational information requires dedicated working memory resources. Nor does it seem too surprising that there is no index of gap-filler integration costs in the form of a late positive response to the head noun, either: postulation of an unambiguous syntactic gap becomes possible only at the head noun itself both in SRs and ORs, as discussed in section 3.2.

It seems that the only operation required at this point in the parse is back association of the filler with the previously detected missing argument of the verb, as indexed by phasic LAN – just as a gap is back associated with a previous filler in a forward filler-gap dependency. Korean ORs with backward gap-filler dependencies elicit a (L)AN effect when compared to SRs at the filler-gap association position (the head noun), just as in comparisons of ORs to SRs at the main clause verb of forward filler-gap dependencies in English relative clauses (King & Kutas, 1995; Weckerly & Kutas, 1999; Müller et al., 1997).

In sum, the processing of backward gap-filler dependencies in Korean relative clauses shows evidence of apparent working memory costs related to the complexity of
operations involved in back associating a filler with a preceding ambiguous gap, as
determined by the depth of embedding of the gap in the relative clause (see section 3.3),
but no storage or integration costs related to the gap itself. This seems perfectly
compatible with general notions of incremental parsing as applied to head-final
languages.

3.4.2 Morphological differences among East Asian languages and their effects on
the processing of pre-nominal relative clauses

As shown in Section 1.2, Chinese, Japanese, and Korean are in many ways
typologically similar. Most relevant to this study is the morphological marking on nouns
and verbs. These typological similarities and differences have immediate implications for
interpreting the ERP results in Ueno & Garnsey’s (2008) study of Japanese RCs, Yang et
al.’s (2010) study of Chinese RCs, and the present study of Korean RCs. In this section,
we attempt to reconcile the experimental results across the three studies. Specifically, for
the comparison of the Japanese and Korean experimental results, we examine the
possibility that the sustained frontal negativity at the embedded verb position reported in
Ueno & Garnsey (2008) corresponds to the sustained frontal negativity within the relative
clause region in the present study. We then turn to the discussion of the major difference
in the experimental results across studies (i.e., presence or absence of late positivity) and
a cross-linguistic difference that is potentially associated (i.e., marking the right edge of
the relative clause).
3.4.2.1 Marking of nouns and the sustained frontal negativity

Recall that in Japanese the greater anterior negativity elicited by ORs started at the embedded verb, i.e., before the head noun (filler) position, and the effect at the head noun position was not statistically reliable, and thus “seems to be a continuation of that evoked by the previous word, the RC verb” (Ueno & Garnsey, 2008:669). Given this, one possibility is that the effect in Ueno & Garnsey may not be related to the processing of the gap-filler dependency in ORs at all. Instead, the effect could be related to the case marking of noun phrases in Japanese, and equivalent to the sustained frontal negativity to NP-NOM within the relative clause region in the present study of Korean. That is, the configuration of the RCs used in Ueno & Garnsey’s study and in the present study is slightly different: in the present study, there is an adverbial phrase between the NP and the verb within the relative clause (i.e., [RC NP-ACC/NOM AdvP VerbRC]) while in the Japanese study, the relative clause verb immediately follows the NP ([RC NP-ACC/NOM Verb]). Thus, although the effect was observed at different sentential positions in Ueno & Garnsey’s study (i.e., the embedded relative clause verb) and in the present study (i.e., the adverbial phrase), the effects in the two studies could be similar in nature since both were observed immediately following NP-NOM. This suggests that the effect at the embedded relative clause verb in Ueno & Garnsey’s study could be a reflection of one of the typological similarities between Japanese and Korean, namely case marking of noun phrases, and an index of the costs associated with the processing of overt nominative-marked NPs in these languages (see section 3.1), independent of the presence of a filler-gap dependency.
3.4.2.2 Marking of relative clause verbs and (sustained) late positivity

Recall that in Ueno & Garnsey’s (2008) study of Japanese relative clauses there was a late positive response at the head noun position. However, ORs in Korean elicited only a LAN, just as in English relative clauses, with no late positivity at or after the head noun position. This difference could be due to the lack of a morphological marker for relative clauses in Japanese. In Japanese, the parser has to construct an embedded clause at the relatively unexpected head noun position if this representation had not been projected earlier, and this process could be especially difficult when the parser also has to integrate a more deeply-embedded gap (i.e., an object gap) with the head noun at the same position (Ueno & Garnsey, 2008); hence the enhanced late positivity to ORs. This is different from the processing of Korean relative clauses, in which the adnominal marker at the relative clause verb clearly signals that a noun will follow the current clause, and thus a head noun is expected.

The one ERP study of Chinese relative clauses (Yang et al., 2010) available in the literature at the time of this writing does not allow a detailed comparison of the effects within the relative clause region with those of the present study due to the complex structure of the experimental sentences (i.e., center-embedded SRs vs. center-embedded garden-pathed ORs). However, overall Chinese seems to pattern more closely with Korean than with Japanese: there is a central-frontal sustained negativity to ORs in comparison to SRs at the head noun position but no subsequent effect of late positivity. This similarity in the ERP responses to the head nouns of Korean and Chinese ORs is probably due to the fact that relative clauses are marked at the right edge in both languages. This provides further evidence that the differences in the ERPs to the head
nouns of Korean and Japanese ORs are due to the differences in morphological marking of the relative clause (yes in Korean, no in Japanese).

3.4.2.3 Mixed results across several Chinese studies

One remaining question is why there is so much variation in the experimental results in Chinese. One possibility is that the mixed results in Chinese are caused by the mixed headedness and concomitant parsing strategies for relative clauses in this language. In general, Chinese pre-nominal relative clauses can initially be misanalyzed as root clauses; this analysis may need to be revised later as more structural cues (e.g., the clitic –de) become available.

For SRs (23), this initial misanalysis is not particularly helpful because the sequence is in an order which is not otherwise available in Chinese: VOS. On the other hand, in ORs (24), because of head-initial SVO word order and the head-final nature of pre-nominal relative clauses, this initial misanalysis coincides exactly with the canonical word order in root clauses: SVO. Accordingly, when the parser expects an object but encounters a -de instead, the reanalysis may not be difficult at all, since the expected object becomes immediately available at the next word position, and so the proper sentential interpretation is readily available (cf. Kanno, 2007; Yip & Matthews, 2007). That is, since the interpretation of the initial misanalysis (i.e., the canonical word order analysis)
is identical to that of the revised structure (i.e., the OR analysis) in terms of *who did what to whom*, this could actually facilitate the processing of ORs in Chinese. This possible processing strategy could account for the OR processing advantage in some of the experimental studies in Chinese.

4 Conclusion

This paper investigated the brain responses elicited by relative clause constructions in Korean, namely phasic anterior negativity to the head noun position. This response seemed most similar to that elicited by Chinese relative clauses. We suggested that this was because the relative clause not only precedes the head noun but is also morphologically marked at its right edge in these languages. Moreover, these results clearly demonstrated similarity in the processing of backward and forward dependencies in relative clauses of typologically distinct languages: Korean ORs with backward gap-filler dependencies elicited phasic anterior negativity in comparison to SRs at the gap-filler association position (i.e., the head noun position), just as English RCs with forward filler-gap dependencies elicit phasic anteriority negativity at the filler-gap association position (i.e., the main clause verb position). This offers further support for the universal processing advantage of SRs over ORs in both types of dependencies. Our experimental results overall support processing models based on language universals: the accessibility hierarchy (Keenan & Comrie, 1977) and the phrase-structural distance hypothesis (O’Grady, 1997).
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Endnotes

1 Readers may wish to skim or skip over sections devoted to concepts with which they are familiar, but are encouraged to pay attention to sections with which they may be less familiar. The extensive background we provide will be crucial to the interpretation of our results, as Korean is relatively understudied with respect to its processing parameters, which in turn reflect its typological properties.

2 For details of this proposal, see Section 1.3.

3 VO languages can be head-initial or verb-medial, but not head-final, while OV languages are always head-final; in what follows we will thus be using the labels OV and head-final interchangeably.

4 For expository purposes we present a simplified version of Hawkins’ proposal; for the full proposal, cf. Hawkins (1990).

5 This misanalysis as a main rather than a relative clause has been attributed to the minimal attachment parsing heuristic, in which the parser by default assumes the simplest structure possible (Frazier, 1985; Hawkins, 1990).

6 Although two studies (Nakamura, 2000; Ishizuka et al., 2006) have reported a processing advantage for ORs in Japanese, Nakamura (2000) attributed her result to a garden path effect associated with SRs (Kanno & Nakamura, 2001). When the experimental sentences were controlled for this garden path effect, the OR advantage disappeared and a SR advantage emerged (Kanno & Nakamura, 2001). Similarly, the OR processing advantage reported by Ishizuka et al. (2006) was not replicated in follow-up studies, and they in fact found a SR processing advantage in their second follow-up
experiment (Tomoko Ishizuka and Ted Gibson, personal communication; see also Kwon et al., 2010, for detailed discussion of Ishizuka et al., 2006).

7 Among numerous SOV languages only Abkhaz (Hewitt, 1979) seems to be a language without such overt case marking. On the contrary, a large proportion of SVO languages have no case marking (Mallinson & Blake, 1981: 101).

8 This clitic is glossed as –Adn for ease of exposition, but it is more accurately used for various kinds of subordination and modification relationships within noun phrases in Chinese: adjectives, possessives, nominal and clausal complements, and relative clauses. At any rate, in these examples, the clitic clearly marks the end of a relative clause preceding the head noun, the main clause subject ‘reporter’.

9 The adnominal marker –nu attached to the embedded verb is not a relative clause marker in Korean, either, as it also marks the complement clauses of abstract head nouns, as in [The fact [that the reporter attacked the senator]] surprised the press corps. See section 2 for detailed discussion.

10 For detailed discussion of accounts based on gap postulation and reactivation of missing argument slots, please refer to Kwon et al. (2010) and Gibson & Wu (under revision).

11 The negativity initiated at the onset of the dependency, however, does not increase cumulatively across the course of the dependency (King & Kutas, 1995; Philips et al., 2005; Hagiwara et al. 2007). That is, a sustained anterior negativity is sensitive to the presence of a dependency but not to its length.
There is one ERP study of Basque, an ergative, head-final language with pre-nominal relative clauses (Carreiras et al., 2010). The authors of this study reported an effect of late positivity in response to the disambiguation point of subject vs. object relative clauses that contained a temporary ambiguity; however, the polarity, latency, and distribution of this ERP effect was equivocal. The authors moreover proposed that the OR advantage could be accounted for in terms of sensitivity to the absolutive-ergative distinction in Basque (in ergative languages, the absolutive is often a privileged argument for relativization, see Dixon, 1994). However, as shown by Polinsky et al. (submitted), this result directly follows from frequency effects. We do not consider the impact of ergativity here, but instead base our predictions on studies of East Asian languages with accusative-nominative alignment that are typologically more comparable to Korean.

Relative clauses with possessive head nouns were selected to control for parallel grammatical function (Sheldon, 1974). In the parallel grammatical function hypothesis (Sheldon, 1974), relative clauses are processed better when the head noun carries the same grammatical function in both main and relative clauses. Thus, for example, SRs with subject head nouns and ORs with object head nouns have an advantage over ORs with subject head nouns and SRs with object head nouns, respectively. SRs and ORs with possessive head nouns do not share this confound, since both constructions involve different grammatical roles for the head noun in the relative and main clauses.

A relative clause with a possessive head noun is structurally ambiguous in Korean, such that the relative clause could be interpreted as modifying either the first or the second NP (e.g., ‘senator-GEN or office-to’ in (15) and (16)). To remove this ambiguity,
only inanimate NPs (e.g., ‘office-to’) were used as the second noun, while a human head noun (e.g., ‘senator-GEN’) was required by the relative clause verb.

15 The experimental stimuli were newspaper-style sentences and the relatively low acceptability ratings seem to be due to their complex structure (see fns. 13, 14, and 19) and high-level vocabulary.

16 Thus, all told, participants saw 40 subject relative sentences, 80 object relative sentences, 40 sentences containing adjunct clauses with dropped object arguments, 35 sentences with scrambled direct objects, 35 sentences containing a headedness violation, 35 sentences containing a semantic violation, and 105 well-formed monoclausal sentences with no dependency formation. If anything, the overrepresentation of object dependencies (forward syntactic [scrambling], backward syntactic [ORs], and backward referential [adjunct clauses with dropped objects]) in the stimulus set should have facilitated the processing of ORs compared to SRs. However, as the results show (see section 2.3), this was not the case.

17 The total number of participants actually run was 24. However, two participants were excluded from analyses due to excessive EEG artifacts.

18 Since at the time of this study there were no previous ERP results for Korean reported in the literature, the presentation rate was based on gaze durations in eye-tracking studies and the responses of four participants in pilot experiments. The average reading time for first pass reading per *ejel* in eye-tracking studies is about 400 ms (Kwangil Choi, Yoonhyoung Lee, and Youngjin Kim, personal communication). In pilot experiments, volunteers were presented with experimental sentences in blocks at different presentation
rates (400 ms duration with 650 ms SOA, 300 ms duration with 500 ms SOA, and 200 ms duration with 400 ms SOA) and rated each presentation speed in terms of their understanding of the sentences and the naturalness of the reading speed. The presentation order of each block was different for each participant. Participants reported that although they could understand sentences at the fastest presentation rate (200 ms presentation with 400 ms SOA), they felt most comfortable and natural with presentation rates of 500 ms SOA.

The relatively lower comprehension accuracy rate for SRs and ORs was most likely due to the balanced plausibility of events described in the stimulus sentences. That is, as discussed in section 2.2.1, the events described in SRs and ORs were matched for plausibility. This led to the use of similar types of professions in one sentence (e.g., SR: ‘A conductor invited a vocalist’ OR: ‘A vocalist invited a conductor’), and likely made experimental stimuli more difficult to comprehend. Cf. also fns. 13, 14 and 15.

Statistical analyses of the 16 individual electrodes included in the distributional analysis showed significant main effects of relative clause type at left lateral frontal (F(1, 21) = 4.53, p < 0.045), left medial frontal (F(1, 21) = 5.25, p < 0.032), left lateral temporal (F(1, 21) = 6.81, p < 0.016), right medial frontal (F(1, 21) = 6.06, p < 0.022), and right medial parietal (F(1, 21) = 4.57, p < 0.044) electrodes, and marginally significant main effects of relative clause type at left medial prefrontal (F(1, 21) = 3.36, p < 0.081), left medial parietal (F(1, 21) = 3.20, p < 0.08), left medial occipital (F(1,21) = 3.79, p < 0.065), and right medial occipital (F(1, 21) = 3.01, p < 0.097) electrodes.
The one difference we did observe was the lack of any apparent response to the gap position in our scrambled filler sentences (21b), in contrast to reports of phasic LAN (Ueno & Kluender, 2003) and P600 effects (Ueno & Kluender, 2003; Hagiwara et al., 2007) elicited by words surrounding gap positions in Japanese scrambled sentences. We have no ready explanation for this apparent cross-linguistic discrepancy at this time.

This lack of late positivity in response to the second element (i.e., the head noun) of a backward gap-filler dependency in a pre-nominal Korean relative clause contrasted as well with the reported late positivity in response to the second element (i.e., the gap) in a forward filler-gap dependency in Japanese scrambling contexts (Ueno & Kluender, 2003; Hagiwara et al., 2007). As reported above in fn. 21, however, we observed no differences in the ERPs to the words preceding (hayngsa-ey, ‘event-to’) or following (chotayhay-ss-ta, ‘invite-PST-DECL’) the gaps in our Korean scrambled sentences (21b).

Miyamoto suggests that the nominative-marked NP signals an inflection-related node with tense (an IP node in Government and Binding theory or TP node in the Minimalist Program), and “provides a fixed point around which other NPs in the sentence can be interpreted” (Miyamoto, 2002: 340; cf. pivot: Foley & Van Valin, 1984; relational figure, clause-level trajector: Langacker, 1991; sentence topic: Reinhart, 1982). However, if the parser is predictive (Altman & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003) and immediately projects a structure with an underspecified head (i.e., it projects a syntactic head despite the lack of exact lexical and argument structure information) cued by local information (Sturt & Crocker, 1996; Yamashita, 1994; Miyamoto, 2002; cf. Pritchett,
1991), it is not clear why an inflection-related node is not signaled by any other sentential arguments (e.g., a sentence-initial topic-marked NP or an accusative-marked NP).

Anterior negativities have of course also been elicited in response to phase-structural or morphosyntactic violations (Kutas & Hillyard, 1983; Neville, Nichol, Barss, Forster, & Garrett, 1991; Friederici, Pfeifer, & Hahne, 1993; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998; Gunter, Stowe, & Mulder, 1997; Osterhout & Mobley, 1995; Coulson, King, & Kutas, 1998; Martín-Loeches et al., 2005). However, the grammaticality of the SR and OR experimental sentences in the present study as well as their very similar plausibility (2.5 vs. 2.6) and comprehension accuracy (70% vs. 68%) scores suggest that the anterior negativity elicited at the head noun position was more likely related to the working memory costs associated with processing a filler-gap dependency (Kluender & Kutas, 1993a; King & Kutas, 1995).
Figures & Tables
Figure 1 Phrase structure of SRs and ORs
Figure 2 (A) Grand average ERP waveforms for grammatical ('the.park-to'; solid line ———) and ungrammatical ('*to-the.park'; dotted line ·······) conditions shown at all 26 electrode sites. (B) Grand average ERP waveforms for grammatical (——) and ungrammatical (········) conditions shown at the medial parietal electrode (the electrode in the dotted squares in A). (C) Topographic scalp isovoltage map of the mean difference (Ungrammatical – Grammatical conditions; 500 - 800 ms).
Figure 3 (A) Grand average ERP waveforms at the sentence final verb position for congruous (meal-ACC ate ‘ate a meal’; solid line — ) and incongruous (book-ACC ate ‘ate a book’; dotted line ··········) conditions shown at all 26 electrode sites. (B) Grand average ERP waveforms for congruous (—— ) and incongruous (·········) conditions shown at the right medial central electrode (the electrode in the dotted squares in A). (C) Topographic scalp isovoltage map of the mean difference (Incongruous – Congruous conditions; 300 - 600 ms)
Canonical word order ——: that kindergarten-GEN principal-NOM
Scrambled word order ···············: parents-ACC that kindergarten-GEN principal-NOM

Figure 4 (A) Grand average ERP waveforms at the nominative marked NP for canonical (solid line —— and scrambled word order (dotted line ···············) conditions shown at all 26 electrodes site. (B) Grand average ERP waveforms for canonical (—— ) and scrambled (··················) word order conditions shown at the left medial frontal electrode (the electrode in the dotted squares in A). (C) Topographic scalp isovoltage map of the mean difference (Scrambled – Canonical word order conditions; 400 - 600 ms).
Figure 5 (A) Grand average ERP waveforms for SR ('publisher-ACC secretly politically exploit-ADN senator-GEN'; solid line —— ) and OR ('publisher-NOM secretly politically exploit-ADN senator-GEN'; dotted line ·········) conditions at NP-ACC/NOM shown at the left lateral frontal electrode.
Figure 6 (A) Grand average ERP waveforms for SR ('publisher-ACC secretly'; solid line ———) and OR ('publisher-NOM secretly'; dotted line ·······) conditions at NP-ACC/NOM shown at all 26 electrodes sites. (B) Grand average ERP waveforms for SR (—— and OR (······) at the left lateral frontal electrode (the electrode in the dotted square in A). (C) Topographic scalp isovoltage map of the mean difference (OR - SR conditions; 300 - 600 ms).
Figure 7 (A) Grand average ERP waveforms for SR (solid line ———) and OR (dotted line ·······) conditions at the relative clause verb and head noun positions (‘exploit-ADN senator-GEN office-to’) shown at all 26 electrodes sites. (B) Grand average ERP waveforms for SR (——) and OR (······) conditions shown at the left lateral frontal electrode (the electrode in the dotted squares in A). (C) Topographic scalp isovoltage map of the mean difference at the relative clause verb (OR - SR conditions; 300 - 600 ms). (D) Topographic scalp isovoltage map of the mean difference at the head noun (OR - SR conditions; 800 - 1100 ms post-stimulus onset of the relative clause verb).
Figure 8 (A) Grand average ERP waveforms for SR (solid line ———) and OR (dotted line ····) conditions at the head noun positions ('senator-GEN office-to') shown at all 26 electrodes sites. (B) Grand average ERP waveforms for SR (- - - - ) and OR (······) conditions shown at the left lateral frontal electrode (the electrode in the dotted squares in A). (C) Topographic scalp isovoltage map of the mean difference at the head noun (OR - SR conditions; 300 - 600 ms).
<table>
<thead>
<tr>
<th>Table 1 SR and OR in English, Japanese, Chinese and Korean</th>
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<tbody>
<tr>
<td><strong>English</strong></td>
</tr>
<tr>
<td>(1)</td>
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<tr>
<td>The reporter ([RC who _i attacked the senator] admitted the error.</td>
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<tr>
<td>FILLER &amp; GAP</td>
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<tr>
<td>(b) post-nominal object relative clause with filler-gap ordering</td>
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<tr>
<td>The reporter ([RC who the senator attacked _i ] admitted the error.</td>
</tr>
<tr>
<td>FILLER &amp; GAP</td>
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<tr>
<td>(2)</td>
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<tr>
<td>(a) pre-nominal subject relative clause with gap-filler ordering</td>
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<tr>
<td>((The) [RC _i attacked senator] reporter, admitted the error. )</td>
</tr>
<tr>
<td>GAP &amp; FILLER</td>
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<tr>
<td>‘~The senator-attacking reporter admitted the error.’</td>
</tr>
<tr>
<td>(b) post-nominal object relative clause with filler-gap ordering</td>
</tr>
<tr>
<td>((The) [RC senator attacked _i ] reporter, admitted the error.</td>
</tr>
<tr>
<td>FILLER</td>
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<tr>
<td>‘~The attacked-by-a-senator reporter admitted the error.’</td>
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<td>(3)</td>
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<tr>
<td>([RC _i Git-ga hinanshita] kisha, -ga ayamari-o mitometa senator-ACC attacked reporter-NOM error-ACC admitted )</td>
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<td>(b) pre-nominal object relative clause with gap-filler ordering</td>
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<td>GAP &amp; FILLER</td>
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<td>(4)</td>
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<tr>
<td>([RC _i gongji yiyuan]-de jizhi, chengren-le cuowu attack senator-ADN reporter admit-PERF error )</td>
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<tr>
<td>GAP &amp; FILLER</td>
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<tr>
<td>(b) pre-nominal object relative clause with gap-filler ordering</td>
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<tr>
<td>([RC yiyuan gongji _i ]-de jizhi, chengren-le cuowu senator attack -ADN reporter admit-PERF error )</td>
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<tr>
<td>(5)</td>
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<tr>
<td>([RC _i uywon-ul kongkyekha-n] kica, -ka silswu-lul siinhayssta senator-ACC attack-ADN reporter-NOM error-ACC admitted )</td>
</tr>
<tr>
<td>GAP &amp; FILLER</td>
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<td>(b) pre-nominal object relative clause with gap-filler ordering</td>
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<td>([RC uywon-i _i kongkyekha-n] kica, -ka silswu-lul siinhayssta senator-NOM attack-ADN reporter-NOM error-ACC admitted )</td>
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<td>Japanese</td>
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<td>Korean</td>
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<td>Chinese</td>
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Table 2 Typological features of interest in Japanese, Korean and Chinese
SR: ‘Gangs attacked the office of the senator who secretly took advantage of the publisher of the newspaper for political purposes’

OR: ‘Gangs attacked the office of the senator who the publisher of the newspaper secretly took advantage of for political purposes’

Table 3 Summary of predictions
### Table 4 Summary of results

<table>
<thead>
<tr>
<th>SR/OR</th>
<th>RC verb</th>
<th>main clause region</th>
</tr>
</thead>
</table>
| SR    | iyonha-n        | uywon-uy  \\      samwusil-ey  \\    kkangphay-ka  \\    tulichyessta  \\    gang-
| OR    | exploit-REL     | senator-GEN office-to              |