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COGNITIVE AND LINGUISTIC FACTORS AFFECTING SUBJECT/OBJECT ASYMMETRY: AN EYE-TRACKING STUDY OF PRENOMINAL RELATIVE CLAUSES IN KOREAN

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Object relatives (ORs) have been reported to cause heavier processing loads than subject relatives (SRs) in both pre- and postnominal position (prenominal relatives: Miyamoto & Nakamura 2003, Kwon 2008, Ueno & Garnsey 2008; postnominal relatives: King & Just 1991, King & Kutas 1995, Traxler et al. 2002). In this article, we report the results of two eye-tracking studies of Korean prenominal relative clauses that confirm a processing advantage for subject relatives both with and without supporting context. These results are shown to be compatible with accounts involving the accessibility hierarchy (Keenan & Comrie 1977), phrase-structural complexity (O'Grady 1997), and probabilistic structural disambiguation (Mitchell et al. 1995, Hale 2006), partially compatible with similarity-based interference (Gordon et al. 2001), but incompatible with linear/temporal analyses of filler-gap dependencies (Gibson 1998, 2000, Lewis & Vasishth 2005, Lewis et al. 2006).*

Keywords: syntax, working memory, sentence processing, relative clauses, Korean, eye-tracking

1. Introduction. The patterning of relative clauses (RCs) across languages displays one of the most robust and interesting generalizations in crosslinguistic research. As described in the accessibility hierarchy of Keenan & Comrie 1977, there is an ordering of grammatical relations (1) such that if a language allows relativization of one grammatical position in this ordering, then it must also allow relativization of all grammatical positions to the left of this position in the hierarchy.

(1) subject > direct object > indirect object > oblique

That is, if a language can relativize obliques, it can also relativize direct and indirect objects and subjects. If a language can relativize objects, it can also relativize subjects, but not necessarily obliques. This pattern of crosslinguistic grammaticality is mirrored in English by the relative frequency with which different types of RCs are used: the higher the grammatical position in the hierarchy, the greater the frequency with which RCs are formed on that position (Keenan 1975, Gordon & Hendrick 2005; cf. Fox 1987, Fox & Thompson 1990).

An attractive way to explain these strong preferences for extraction from higher positions in the accessibility hierarchy is to say that the preferences arise from the cognitive

mechanisms that underlie human sentence processing, as originally proposed by Keenan and Comrie (1977). Support for this approach comes from the attested subject/object asymmetry in human sentence processing, in which relative-clause sentences with object gaps (ORs) are found to be more difficult to process than relative-clause sentences with subject gaps (SRs).

[AQ 1]   [1] This subject/object asymmetry has been demonstrated in first and second language acquisition (first language acquisition: Sheldon 1974, Tavakolian 1978, de Villiers et al. 1979, Lempert & Kinsbourne 1980, Friedmann & Novogrodsky 2004, Diessel & Tomasello 2005; second language acquisition: Gass 1979, Eckman et al. 1988, Doughty 1991, Hamilton 1994, O'Grady et al. 2003), in the loss of language ability resulting from aphasia (Caplan & Futter 1986, Grodzinsky 1989, Lukatela et al. 1995), in measures of brain activity (ERP: King & Kutas 1995, Müller et al. 1997, Münte et al. 1997; fMRI: Just et al. 1996, Caplan et al. 2001, 2008, Cooke et al. 2001, Constable et al. 2004, Chen et al. 2006; PET: Stromswold et al. 1996, Caplan et al. 1998, 1999, 2000), and by using a variety of behavioral measures of language comprehension (memory-load recall and comprehension: Wanner & Maratsos 1978; reading time: King & Just 1991; eye-tracking: Traxler et al. 2002). Evidence for this asymmetry is thus plentiful, arising from numerous methodologies and populations. A high proportion of this data, however, is from languages in which the relative clause (RC) occurs postnominally, that is, after the head noun it modifies (e.g. English). By contrast, there has been less abundant psycholinguistic evidence for such a subject/object asymmetry in languages with prenominal RCs, where many of the detailed cognitive explanations that have been developed to account for the asymmetry in languages with postnominal RCs do not predict the same asymmetry (Gibson 1998, 2000; for individual languages see also—Chinese: Hsiao & Gibson 2003, C. Lin 2006, 2008, C. Lin & Bever 2006, Kuo & Vasishth 2006, Y. Lin & Garnsey 2007, Gibson & Wu 2010; Japanese: Miyamoto & Nakamura 2003, Ishizuka et al. 2006, Ueno & Garnsey 2008; Korean: Kwon 2008; Basque: Carreiras et al. 2010).

Here we report two experiments on the comprehension of Korean—a language with prenominal RCs—that provide novel empirical data for evaluating theoretical explanations of the subject/object asymmetry. We first review the structure of sentences with RCs in Korean. In doing so, we focus on predictions about the subject/object asymmetry in different types of Korean sentences made by specific theoretical proposals that invoke cognitive mechanisms to explain the asymmetry. We then report the results of two eye-tracking experiments that test the accuracy of these predictions and ask whether current parsing theories are sufficient to account for the observed asymmetry in processing Korean relative-clause sentences.

1.1. KOREAN. Korean is a head-final language with subject-object-verb (SOV) word order. Grammatical roles of clause constituents are indicated by nominative, accusative, and genitive case markers. When case markers are omitted, however, as they often are in casual speech, word order is an important indicator of grammatical function. Since it is a *pro*-drop language, arguments can be omitted in Korean; *pro*-drop is typical for

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[1] The terms subject relative (SR) and object relative (OR) are commonly used in the experimental literature; it is worth noting, however, that these terms are somewhat imprecise. The reader should bear in mind that 'subject relative' is shorthand for a subject-extracted relative clause, and 'object relative' for an object-extracted relative clause. Note also that we are not considering internally headed relative clauses otherwise attested in Korean (cf. M. Kim 2007, 2009).

both subjects and objects (Y. Kim 2000). Dropped arguments must be identifiable in the current context (Huang 1984) or receive an arbitrary reading.[2]

(2) Yenghuy$_i$-ka cip-ey   wassta. Kuliko __$_i$ pap-ul   mekessta.
    Y-NOM   home-to came   and   __ meal-ACC ate
      'Yenghuy came home. Then (she) ate a meal.'

Sentence-initial clauses in Korean are temporarily ambiguous between a main-clause and an embedded-clause reading, a property of the language that we investigate in experiment 1. In head-initial languages like English, a sentence-initial subordinate clause is marked with a subordinator at its outset. Thus an initial unmarked clause can safely be taken to be a main clause (cf. structural ambiguity in head-initial languages: Frazier & Fodor 1978). By contrast, in head-final languages like Korean and Japanese, while an embedded clause always precedes the main clause, subordinators come at the end of the embedded clause as morphemes attached to the clause-final verb, triggering a temporary structural ambiguity between a main- and an embedded-clause reading for any sentence-initial clause.

This ambiguity applies to RCs as well. RCs in Korean, unlike in English, precede the head noun they modify and lack a relative pronoun—a typological feature commonly associated with prenominal relatives (Downing 1978, Keenan 1985). Instead, an adnominal marker is suffixed to the clause-final verb to signal that the clause modifies, as in 3, or serves as the complement of a noun, as in 6 below.

(3) 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'

Thus a sentence-initial RC may be interpreted as a main clause rather than as a subordinate clause before the parser reaches the verb with the adnominal marker, leading to a potential garden-path effect. For example, when parsing subject RCs as in 3 above, the parser might initially attach *Yenghuy* as the object of the main clause, assuming either that the subject has been dropped or that the object has been scrambled to the clause-initial position. This reading needs to be revised subsequently at the embedded verb position ('meet-ADN'), with *Yenghuy* attached as the object of the embedded clause instead.

A gap in Korean is moreover temporarily ambiguous between a dropped argument or part of an RC. For example, the sentence fragment in 4 could turn out to contain a dropped argument in a simple clause, as in 5, or in a complex clause, as in 6. Alternatively, it could be a part of an RC, as in 3. Note that the use of the adnominal marker is not exclusive to RCs, as shown in 6: here, the adnominal marker is used to mark the sentential complement of the head-noun 'fact'. The potential effects of this temporary structural ambiguity on processing are addressed in experiment 2.

(4) Structural ambiguity of a gap
    [__ Yenghuy-lul hakkyo-eyse]
    [__ Y-ACC   school-at]

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[2] We use the following abbreviations in glossing our examples: ACC: accusative, ADN: adnominal, COMP: complementizer, DECL: declarative, GEN: genitive, HON: honorific, IND: indicative mood, NOM: nominative, PRES: present tense/aspect, PST: past/perfect aspect, Q: question, and TOP: topicalizer.

(5) 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.'

(6) Argument drop in fact-CP clause
    [__ Yenghuy-lul hakkyo-eyse manna-n]   sasil
    [__ Y-ACC   school-at   meet-ADN] fact
      'the fact that (someone) met Yenghuy at school'

Prenominal RCs can occur in a variety of sentence structures, as illustrated in the examples below, with subject-modifying RCs shown in 7 and 8, in-situ object-modifying RCs shown in 9 and 10, and scrambled object-modifying RCs shown in 11 and 12, in which the object plus its modifying clause is fronted to the sentence-initial position, thus preceding the subject.

(7) Subject relative clause modifying the matrix subject
    [$\_\_\_i$ uywon-ul   kongkyekha-n] enlonin$_i$-i   phyencipcang-ul
    [__ senator-ACC attack-ADN]   journalist-NOM editor-ACC
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist who attacked the senator disliked the editor.'

(8) Object relative clause modifying the matrix subject
    [uywon-i $\_\_\_i$ kongkyekha-n] enlonin$_i$-i   phyencipcang-ul
    [senator-NOM __ attack-ADN]   journalist-NOM editor-ACC
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist who the senator attacked disliked the editor.'

(9) Subject relative clause modifying the matrix object in situ
    enlonin-i   [$\_\_\_i$ uywon-ul   kongkyekha-n] phyencipcang$_i$-ul
    journalist-NOM [__ senator-ACC attack-ADN]   editor-ACC
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist disliked the editor who attacked the senator.'

(10) Object relative clause modifying the matrix object in situ
    enlonin-i   [uywon-i $\_\_\_i$ kongkyekha-n] phyencipcang$_i$-ul
    journalist-NOM [senator-NOM __ attack-ADN]   editor-ACC
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist disliked the editor who the senator attacked.'

(11) Subject relative clause modifying the scrambled matrix object
    [[$\_\_\_i$ uywon-ul   kongkyekha-n] phyencipcang$_i$-ul]$_j$ enlonin-i $\_\_\_j$
    [__ senator-ACC attack-ADN]   editor-ACC   journalist-NOM __
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist disliked the editor who attacked the senator.'

(12) Object relative clause modifying the scrambled matrix object
    [[uywon-i $\_\_\_i$ kongkyekha-n] phyencipcang$_i$-ul]$_j$ enlonin-i $\_\_\_j$
    [senator-NOM __ attack-ADN]   editor-ACC   journalist-NOM __
        silheha-n-ta
        dislike-PRES-DECL
      'The journalist disliked the editor who the senator attacked.'

In discussing these types of sentences, we focus on four characteristics that have been hypothesized to differentially affect the ease of processing of SRs and ORs: memory decay associated with linear/temporal distance, phrase-structural complexity, probabilistic structural disambiguation, and the similarity of successive NPs with the same case marking.

1.2. LINEAR AND TEMPORAL DISTANCE. In activation-based models of sentence processing, processing difficulty is accounted for in terms of memory activation and subsequent decay in working-memory stores. For example, in English relative clauses, while filler-gap integration requires computational resources to a certain degree, longer-distance integration is hypothesized to be more expensive due to memory decay over distance. Theoretical accounts vary with respect to whether they characterize distance in terms of specific types of linguistic units (e.g. Gibson 1998, 2000, Warren & Gibson 2002) or in terms of time (Lewis & Vasishth 2005, Lewis et al. 2006). Accordingly, the subject/object processing asymmetry in postnominal relative clauses has been accounted for in terms of the longer linear/temporal distance in ORs (14) vs. SRs (13) (see also Wanner & Maratsos 1978, Just & Carpenter 1992). A gap is immediately activated at filler both in SRs and ORs (Frazier & Clifton 1989), and thus the linear/temporal distance that the parser has to maintain information about the filler in expectation of the gap is longer in ORs (14) than in SRs (13).

(13) Subject relative clause
   The reporter$_i$ [who$_i$ ___$_i$ attacked the senator] disliked the editor.
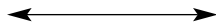
(14) Object relative clause
   The reporter$_i$ [who$_i$ the senator attacked ___$_i$] disliked the editor.

Predictions in Korean prenominal relative clauses are more complex. For example, one might assume that a filler is integrated with its gap in its canonical position within the relative clause, as was the case for English RCs. It should be borne in mind, however, that the gap is encountered first in Korean—before the filler—and has no phonetic content of its own; moreover, there is no relative pronoun in Korean to explicitly signal the presence of a gap. Thus, the presence of a gap can be inferred only indirectly from other local cues. For example, under incremental parsing (Sturt & Crocker 1996, Miyamoto 2002), a gap would be postulated at the noncanonical sentence-initial NP-ACC in SRs (15), while in ORs (16) it would be postulated at the embedded predicate, as the argument structure of the transitive verb will signal a missing argument. Accordingly, on this view, SRs exhibit longer linear/temporal distance between the gap and the filler than ORs (solid arrows).[3] This predicts a processing disadvantage for SRs at the head noun, the opposite pattern from the one observed in languages with postnominal RCs.

Alternatively, while gap postulation may occur at different positions in SRs ('senator-ACC' in 15) and ORs ('attack-ADN' in 16), it remains the case that all previously parsed arguments will need to be reactivated at the embedded-clause verb for proper interpretation

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[3] The gap in Korean RCs has been claimed to either be the trace of syntactic movement (J. Han 1992, C. Han & Kim 2004, Yang 1990, among others) or, on some accounts, the null-argument *pro* (Kang 1986, Sohn 1980). We believe, however, that the linguistic analysis of gaps in Korean RCs is orthogonal to the current discussion of the processing of filler-gap integration, contrary to Miyamoto & Nakamura 2003. This is supported by a recent study showing similar processing profiles for a gap in a relative clause and a *pro* in a minimal-pair adjunct clause (see Kwon 2008 for details).

of the relative clause. This means that while the missing object argument in an OR will not be postulated until the relative-clause verb (16), the previously postulated missing subject argument in an SR (15) will nonetheless also need to be reactivated at this same position. Thus the last point of postulation/reactivation will be identical in SRs and ORs, namely the relative-clause verb, and the linear/temporal distance to the filler will likewise be the same (dashed arrows). Thus, on this view, linear/temporal distance predicts no SR/OR processing asymmetry.[4]

(15) Subject relative clause

GAP POSTULATION   MISSING ARGUMENT REACTIVATION

[__$_i$ uywon-ul kongkyekha-n] enlonin$_i$-i   yumyengha-ta
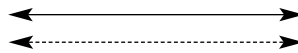[__   senator-ACC attack-ADN]   journalist-NOM is.famous-DECL
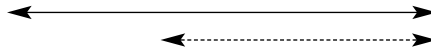
'The journalist who attacked the senator is famous.'

(16) Object relative clause

GAP POSTULATION

[uywon-i   __$_i$ kongkyekha-n] enlonin$_i$-i   yumyengha-ta
[senator-NOM __   attack-ADN]   journalist-NOM is.famous-DECL

'The journalist who the senator attacked is famous.'

To summarize, for Korean prenominal RCs, an account based purely on linear/ temporal distance predicts either an OR processing advantage or no processing asymmetry at all.
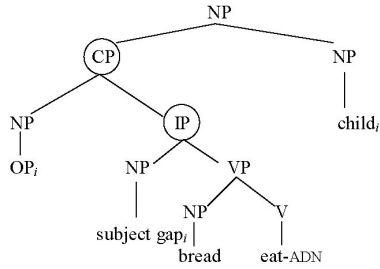
1.3. PHRASE-STRUCTURAL COMPLEXITY. According to this hypothesis, processing difficulty increases with the hierarchical phrase-structural distance between a filler and its gap, as calculated by the number of intervening XP categories (IP, VP, etc.; O'Grady 1997:136). Because the subject gap is always closer to the head noun than the object gap in terms of phrase structure, the structural-distance hypothesis predicts a processing advantage for SRs relative to ORs, regardless of whether RCs in a language are pre- or postnominal. In particular, this hypothesis predicts that this processing asymmetry should be observed at the head-noun position, where a gap and its filler are first associated. These predictions are illustrated in the parse trees in Figure 1, where, for simplicity, we use English to represent Korean.

1.4. EXPERIENCE-BASED MODELS. In experienced-based models of sentence processing, initial parsing decisions are accounted for by prior exposure to language. Here we focus on two such accounts: the TUNING HYPOTHESIS (Mitchell et al. 1995) and the ENTROPY REDUCTION HYPOTHESIS (Hale 2006).[5] In the tuning hypothesis, the SR processing advantage is accounted for in terms of structural frequency. That is, SRs are more frequent than ORs in English (Roland et al. 2007; cf. Fox 1987) and thus the SR reading is favored in the early phases of structural analysis. In the entropy reduction hypothesis,

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[4] We thank a referee for pointing this out.

[5] We do not discuss the surprisal model (Hale 2001, Levy 2008) in this article since this model is not compatible with the English RC processing results (see §8.1 of Levy 2008 for details; cf. Demberg & Keller 2009).

SR: 2 XPs, 'the child who ate bread'   OR: 3 XPs, 'the bread that the child ate'
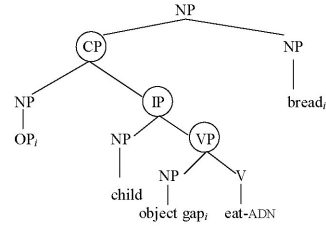
FIGURE 1. Phrase structure of SRs and ORs.

processing difficulty is couched in terms of uncertainty about grammatical continuations as new words enter the parse (i.e. transitional structural ambiguity), all in reference to the probabilistic grammar that one has been exposed to. In this account, SRs are more frequent and have a lesser degree of structural ambiguity than ORs, and are thus easier to process (Hale 2006). In Korean, as in English, SRs are more frequent (Kwon 2008) and show less temporary ambiguity (Yun et al. 2010) than ORs.[6] Therefore, both the tuning hypothesis and the entropy reduction hypothesis predict a processing advantage for SRs. For expository purposes, we henceforth refer to these two experience-based models in the context of 'probabilistic structural disambiguation'.

Apart from the tuning hypothesis and the entropy reduction hypothesis, one observation made in the context of experience-based models that could be relevant in the current experiment is the anti-locality effect: greater distance between the gap and the filler is viewed as facilitatory rather than inhibitory, as the context provided by intervening material can help to sharpen the expectation of an upcoming word with regard to its location and identity (Konieczny 2000, Grodner & Gibson 2005, Vasishth & Lewis 2006, Jaeger et al. 2008, Levy 2008). In our experiment, the sentence-initial noncanonical NP-ACC in SRs (15) would signal a particular type of relative-clause verb (namely transitive), while in ORs (16) there are no such cues to the transitive structure of the clause until the embedded verb position itself is encountered, right before the head noun. Thus, at the following head-noun position, gap-filler integration could be more difficult in ORs than in SRs due to the additional processing difficulty caused by the relative (un)expectedness of the transitive clausal structure.

1.5. CASE MARKERS AND NP SIMILARITY. Similarity models have provided support for the idea that the critical determinant of processing difficulty is not the amount of material that must be held in working memory, nor the amount of time that it must be held, but rather the similarity of intervening material, which is taken to determine the difficulty of processing by causing interference. An early similarity-based interference explanation (Lewis 1996) advanced the idea that human memory has separate storage capacity for different types of information, and that for syntactic dependencies this capacity is at two units of different information. This model, however, was unable to account for the finding that the processing of complex constructions such as RCs and center-embedded sentences is strongly influenced by the types of NPs that appear (Bever 1974, Gibson 1998, Gordon et al. 2001). A number of subsequent models have incorporated similarity-based interference in different ways with respect to whether it

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[6] The computational modeling in Yun et al. 2010 is based on a promotion analysis of relative clauses in Korean (but see Kwon 2008 for arguments against a promotion analysis of Korean relative clauses).

operates during encoding and/or retrieval. The updated models also distinguish whether interference occurs because of similarity between stored items and/or because of similarity in association between retrieval cues and stored items (Gordon et al. 2001, 2002, 2004, 2006, Van Dyke & Lewis 2003, Lewis et al. 2006, Van Dyke & McElree 2006, Lee et al. 2007).

In Korean, Lee and colleagues (2007) manipulated the similarity of adjacent NPs in complex sentences where the first NP was the subject of the main clause and the second NP was the subject of an embedded clause.

> (17) Two subjects
>
> [$_{\text{MAIN CLAUSE}}$ **subject NP$_1$** [$_{\text{EMBEDDED CLAUSE}}$ **subject NP$_2$** $_{\text{EMB}}$verb] $_{\text{MAIN}}$verb].

Their eye-tracking experiments showed elevated reading times at the sentence-initial position (i.e. subject NP$_1$ + subject NP$_2$) when the initial NPs were of the same type (i.e. two descriptive NPs or two pronouns). Importantly, this effect was observed in a measure of later processing (i.e. rereading times). Lee and colleagues take this later processing effect to suggest that similarity-based interference is mainly a phenomenon of memory retrieval: proper interpretation of a Korean sentence requires the retrieval of the initial NPs once readers reach the embedded and matrix verbs at the sentence-final positions, and thus a similarity interference effect is observed in the measure of rereading times.

Apart from the NP type, in Korean RCs, case markers provide another potential source of similarity (or distinctiveness) in working memory that is not present in English. Evidence from studies of the similarity effect in Korean shows that sentence-processing difficulty increases when two successive NPs are both marked with nominative case (-*i/ka*), compared to instances when one of the NPs is marked as topic (-*nun*) (Nakayama et al. 2005). The possible contribution of case-marker similarity to the subject/object processing differences in Korean RCs varies with the overall sentence structure.

For subject-modifying RCs, as in 7 and 8, ORs contain successive NPs with the same (nominative) case marking (19) while SRs do not (18). Because the embedded verb intervenes between the two critical NPs, similarity should not cause processing interference during memory encoding but could interfere during memory retrieval processes that take place after the relevant NPs and verb have been encountered (Lee et al. 2007, Van Dyke & McElree 2006; cf. Lewis et al. 2006). Thus, greater difficulty is predicted in processing ORs than SRs at the head-noun position.

> (18) Subject-modifying SR: no similarity-based interference predicted
>
> [___$_i$ NP-**ACC** Verb-ADN] NP$_i$-**NOM** ...

[AQ2]
> (19) Subject-modifying OR: similarity-based interference predicted
>
> [NP-**NOM** ___$_i$ Verb-ADN] NP$_i$-**NOM** ...

For RCs modifying scrambled objects, 11 and 12, SRs contain successive NPs with the same (accusative) case marking (20) while ORs do not (21). Thus, similarity-based interference predicts that for scrambled object-modifying RCs there should be greater processing difficulty at the head-noun position in SRs than in ORs, the opposite pattern from subject-modifying RCs.

> (20) Scrambled object-modifying SR: similarity-based interference predicted
>
> [___$_i$ NP-**ACC** Verb-ADN] NP$_i$ -**ACC** ...
> (21) Scrambled object-modifying OR: no similarity-based interference predicted
>
> [NP-**NOM** ___$_i$ Verb-ADN] NP$_i$-**ACC** ...

For RCs modifying the matrix object in situ, 9 and 10, the situation is more complex with regard to the sentence-initial matrix subject NP (i.e. NP_1 in 22 and 23). The predictions can be made based on the similarity of the sentence-initial NP and the NP within the relative clause on the one hand (i.e. NP_1 and NP_2), and the NP within the relative clause and the head-noun NP on the other (i.e. NP_2 and NP_3).

(22) In-situ object-modifying SR
     NP_1-**NOM** [___$_i$ NP_2-**ACC** Verb-**ADN**] NP_3 $_i$-**ACC** ...
(23) In-situ object-modifying OR
     NP_1-**NOM** [NP_2-**NOM** ___$_i$ Verb-**ADN**] NP_3 $_i$-**ACC** ...

First, when the sentence-initial NP_1 and NP_2 are considered, the case markers of the two NPs are the same (nominative) for ORs (23) while they are different for SRs (22). Accordingly, similarity-based interference is predicted to occur at the sentence-initial position of ORs (10), in accordance with Lee et al. 2007.

Second, when the NP_2 within the relative clause and the head-noun NP_3 are considered, the case markers of the head-noun and embedded NPs are both the same (accusative) for SRs (22), while they are different for ORs (23). Accordingly, greater processing difficulty is predicted at the head-noun position in SRs than in ORs. It should be noted, however, that SRs (22) likely lead to a garden-path effect in which the two sentence-initial NPs are interpreted as the subject and object of a simple SOV sentence. Such garden-path effects are not possible in the case of object extractions because the two initial NPs are both nominative (23). Thus, at the head-noun position, in-situ object-modifying SRs should incur a processing cost related to the garden-path effect, while in-situ object-modifying ORs should incur an interference processing cost based on similarity of case marking; these two independent processing difficulties may cancel each other out, resulting in either minimal or no differences at the head-noun position of relative clauses that modify in-situ objects.

To summarize, we have discussed four types of models: distance-based models, phrase-structural complexity-based models, experience-based models, and similarity-based models. Models based on LINEAR or TEMPORAL DISTANCE predict that Korean, unlike English, will show either an OR processing advantage or no processing asymmetry. PHRASE-STRUCTURAL COMPLEXITY and EXPERIENCE-BASED MODELS predict an SR processing advantage in both languages. Models based on SIMILARITY OF NPs predict that the processing asymmetry will vary with the type of head noun. The two experiments reported here examine the effects of linear/temporal distance and phrase-structural complexity between filler and gap, and probabilistic structural disambiguation as well as similarity effects caused by case markers.

2. EXPERIMENT 1. Experiment 1 compared the processing of two gap types (subject vs. object RCs) for different types of head nouns in Korean: subject, in-situ object, and scrambled object head nouns, as in 7 through 12.[7] Crucially, regardless of head-noun type, the dependency distance in SRs is greater than or equal to that in ORs when distance is defined in linear or temporal units (for gap-filler association and direct association of head noun and verb, respectively) but shorter than ORs when distance is characterized hierarchically. A similarity-based account predicts an interaction of gap type (subject vs. object) and head-noun type (subject, scrambled, and in-situ object). Under such an ac-

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[7] Scrambling may influence processing (Ueno & Kluender 2003, Miyamoto 2006, Hagiwara et al. 2007), but because the main comparisons were between SR and OR for each head-noun condition, there should be no confound due to scrambling in this study.

count, there should be an OR advantage for scrambled object-modifying RCs, but an SR advantage for subject-modifying RCs and for in-situ object-modifying RCs (see previous section). In the latter case, the SR advantage should be found in retrieval-related processing of the initial two NPs, but similarity effects of the head and embedded NPs may be less clear due to the garden-pathing that occurs during the comprehension of SR sentences.

2.1. PARTICIPANTS. Forty-two native Korean speakers at Korea University participated in this experiment. All had normal or corrected-to-normal vision. They received course credit for their participation.

2.2. MATERIALS. Thirty-six sets of six experimental conditions were taken from experiment 4.1 in Kwon 2008 with modification of the matrix predicates, as shown in 24 to 26.

(24) Subject-modifying RCs
[yumyenghan sengacka-lul/ka   chwukcen-ey chotayha-n]
[famous   vocalist-**ACC/NOM** festival-to   invited-ADN]
     cihwuyca-ka   uywon-ul   kongkongyenhi moyokhay-ss-ta
     conductor-NOM senator-ACC publicly   insult-PST-DECL
   SR: 'The conductor who invited the famous vocalist to the festival publicly insulted the senator.'
   OR: 'The conductor who the famous vocalist invited to the festival publicly insulted the senator.'
(25) Scrambled object-modifying RCs
[yumyenghan sengacka-lul/ka   chwukcen-ey chotayha-n]
[famous   vocalist-**ACC/NOM** festival-to   invited-ADN]
     cihwuyca-lul uywon-i   kongkongyenhi moyokhay-ss-ta
     conductor-ACC senator-NOM publicly   insult-PST-DECL
   SR: 'The senator publicly insulted the conductor who invited the famous vocalist to the festival.'
   OR: 'The senator publicly insulted the conductor who the famous vocalist invited to the festival.'
(26) In-situ object-modifying RCs
     yumyenghan cihwuyca-ka [sengacka-lul/ka   chwukcen-ey chotayha-n]
[famous   conductor-NOM vocalist-**ACC/NOM** festival-to   invited-ADN]
     uywon-ul   kongkongyenhi moyokhay-ss-ta
     senator-ACC publicly   insult-PST-DECL
   SR: 'The famous conductor publicly insulted the senator who invited the vocalist to the festival.'
   OR: 'The famous conductor publicly insulted the senator who the vocalist invited to the festival.'

The plausibility of both subject and object relative clauses was controlled in a norming study (Kwon 2008).[8] In addition, there were forty-eight unrelated filler sentences of comparable sentential complexity.

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[8] Thirty-seven Korean native speakers in Korea rated the naturalness of the sentences. The participants were asked to rate a sentence as 1 if it sounded natural, and as 5 if the sentence sounded strange. The results of the study showed that the two types of relative clauses used in the experiment did not differ from each other in terms of naturalness ($t(36) = 2.94$, $p < 0.1$). The means for naturalness were 2.72 for SRs and 2.89 for ORs.

2.3. DESIGN AND PROCEDURE. Six lists were created using a Latin square design. Across the six lists, each experimental sentence appeared in all six conditions. There were six initial practice sentences. Participants read a single sentence while wearing an EyeLink eye-tracker manufactured by Sensorimotoric Instruments (Boston, MA). The device was fully calibrated before the experiment began and the calibration was checked before each trial. The tracker sampled pupil location at a rate of 250 Hz.

Participants were instructed to read each sentence at a natural pace. Immediately after they finished reading the sentence, participants pressed the space bar on a keyboard to see a true/false comprehension statement. True and false statements were equally distributed across conditions and all the comprehension questions focused on the relative clause. Participants responded by pressing '/' for true and 'z' for false. Eye movements were recorded throughout the experiment.

2.4. EYE-TRACKING MEASURES. Fixations of less than 80 ms were eliminated unless the adjacent fixation fell on the same word. In this case, the fixations were incorporated into larger fixations (for a discussion of this method, see Rayner 1975, 1978). Short fixations made up 2.6% of total fixations; 1.1% were eliminated and 1.5% were combined with the adjacent fixation. Fixations longer than 800 ms were trimmed to 800 ms (0.1% of total fixations) (Folk & Morris 2003).

Gaze duration, regression-path duration, and rereading-time measures were reported as online measures of sentence processing. Gaze duration is the sum of all fixations on a region before the eyes move out of the region to either the right or left (Rayner 1998). This measure is generally regarded as a measure of initial sentence processing. Regression-path duration is the sum of all fixations spent on the target and pretarget regions, from the first fixation in a target region to fixation to the right of the target region (Rayner & Duffy 1986, Liversedge et al. 1998). This measure is known to be sensitive to the detection of processing difficulty at later stages of processing, as is rereading time, which counts all fixations except the initial reading of a region (i.e. gaze duration). Thus, evidence of linear/temporal distance and similarity-based interference, which are related to memory retrieval, should come from these two measures: regression-path duration and rereading times.

2.5. RESULTS.

OVERALL READING TIMES AND ACCURACY. Table 1 summarizes the results for the comprehension questions and overall reading times in experiment 1.

HEAD-NOUN TYPE	GAP TYPE		DIFFERENCE
	SR	OR	OR – SR
subject head	.77	.72	−.05
	6443	8204	1,761
scrambled object head	.77	.76	−.01
	6686	7497	811
in-situ object head	.78	.75	−.03
	6443	6635	192

TABLE 1. Proportion correct on the comprehension questions and overall reading times of the experimental sentences in experiment 1.

Accuracy in answering the comprehension questions did not vary significantly as a function of experimental condition.[9] Total reading times of the experimental, however,

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[9] The experiments resulted in longer reading times with rather lower comprehension accuracy rates (76% overall) than one would normally expect for natural reading. Although low accuracy rates and longer reading

showed a main effect of gap (RC or relative clause) type: reading times were signifi-
cantly shorter for the subject gap conditions than for the object gap conditions
($F1(1,41) = 30.69$, $MSE = 10,441,270$, $p < 0.001$; $F2(1,35) = 21.52$, $MSE = 14,302,468$,
$p < 0.001$). There was also a significant interaction between gap type and head-noun
type: the difference in total reading times between subject gaps and object gaps was
largest for subject head nouns, smallest for in-situ object head nouns, and intermediate
in size for scrambled object head nouns ($F1(2,82) = 8.52$, $MSE = 9,326,058$, $p < 0.001$,
$F2(2,70) = 3.98$, $MSE = 18,790,790$, $p < 0.05$). Pairwise comparisons showed that the
differences between subject gaps and object gaps were significant for subject head
nouns ($p < 0.0001$), and for scrambled object head nouns ($p < 0.001$), but not for in-situ
object head nouns ($p > 0.2$).

GAZE DURATION. Figure 2 shows the gaze duration of each word of the SR and OR
sentences for each of the three head-noun types. Type of gap (SR vs. OR) did not sig-
nificantly affect gaze duration on any of the words in subject (upper panel) and in-situ
object (lower panel) head-noun sentences. For scrambled object head-noun sentences
(upper panel; dashed lines), there was a significant effect of gap type only for the con-
stituent 'senator-ACC' (the W8 region), where the object gap condition took longer to
read than the subject gap condition ($F1(1,41) = 4.34$, $MSE = 16,522$, $p < 0.05$; $F2(1,35)$
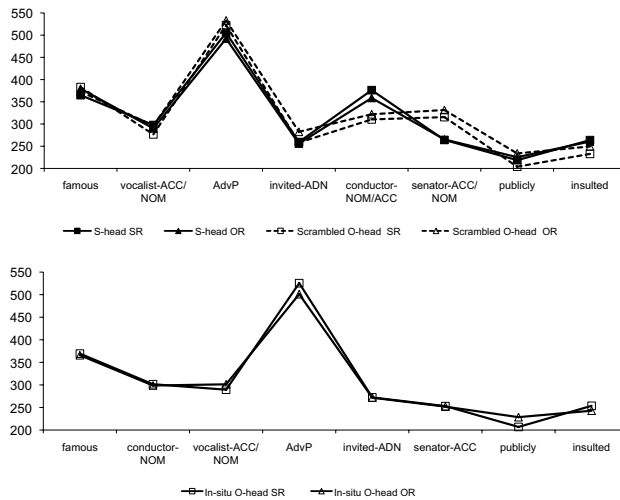$= 5.60$, $MSE = 9,711$, $p < 0.05$).

FIGURE 2. Gaze duration of SRs and ORs across types of head noun of experiment 1.

times are not uncommon in psycholinguistic studies of language and working memory (Hsiao & Gibson 2003
found overall reading times of 5500 ms with only a 72% accuracy rate in a self-paced reading-time study, as
roughly calculated from table 1 and figures 1 and 2), the poor performance in this study is most likely due to
the balanced plausibility of events involving three out-of-the-blue discourse referents in both SR and OR
stimulus sentences. That is, to ensure that plausibility of events would not bias one interpretation over the
other, sentences were carefully devised such that events in both constructions were equally plausible. This,
however, led to the use of similar types of jobs in one sentence (e.g. SR: 'A conductor invited a vocalist'; OR:
'A vocalist invited a conductor'), and could also have made experimental sentences difficult to comprehend.
In addition, although these longer reading times may have allowed for strategic effects to obscure on-line pro-
cessing profiles, overall results in this experiment are consistent with ERP studies using equivalent materials
(Kwon 2008), where sentences were presented with an SOA (stimulus onset asynchrony) of 500 ms.

REGRESSION-PATH DURATION. Table 2 shows regression-path durations for SRs and ORs with different head-noun types. Regression-path durations were calculated for the embedded verb region and the head-noun region.

HEAD TYPE	GAP TYPE	W6	W7	W8
		invited-ADN	conductor-NOM	
S-head	SR	1011	1385	
	OR	1139	1855	
		invited-ADN	conductor-ACC	
scrambled O-head	SR	1010	1381	
	OR	1104	1502	
			invited-ADN	senator-ACC
in-situ O-head	SR		1137	1092
	OR		1155	1062

TABLE 2. Regression-path duration of SRs and ORs across types of head noun in experiment 1.

The embedded verb region ('invited-ADN') was W6 for the subject and the scrambled object head-noun conditions, and W7 for the in-situ object head-noun conditions. There was a marginally significant main effect of gap type (i.e. significant by items but just short of significance by subjects) for this region, indicating that regression-path duration was greater for ORs than for SRs ($F1(1,41) = 3.82$, $MSE = 582,822$, $p < 0.057$; $F2(1,35) = 4.46$, $MSE = 424,082$, $p < 0.05$).

The head-noun region consisted of the word following the embedded verb region (i.e. W7 'conductor-NOM/ACC' for subject and scrambled object head-noun conditions, respectively, and W8 'senator-ACC' for in-situ object head-noun conditions). For this region, there was a main effect of gap type: regression-path duration was significantly longer in ORs than in SRs ($F1(1,41) = 16.61$, $MSE = 736,289$, $p < 0.001$; $F2(1,35) = 9.25$, $MSE = 1,272,453$, $p < 0.004$). In addition, there was a main effect of head-noun type: ($F1(2,82) = 50.34$, $MSE = 731,110$, $p < 0.001$; $F2(2,70) = 42.6$, $MSE = 848,317$, $p < 0.001$). This is presumably due to the shorter reading times in the in-situ object head-noun condition. Finally, there was an interaction of gap type and head-noun type ($F1(2,82) = 12.35$, $MSE = 606,153$, $p < 0.001$; $F2(2,70) = 5.92$, $MSE = 1,292,744$, $p < 0.01$). In this region, the subject/object asymmetry was greatest in the subject head-noun condition, intermediate in the scrambled object head-noun condition, and absent in the in-situ object head-noun condition. Pairwise comparisons showed that the differences between subject gaps and object gaps were significant for subject head nouns ($p < 0.0001$), marginal for scrambled object head nouns ($p < 0.062$), but not significant for in-situ object head nouns ($p > 0.9$). Note that this pattern is similar to what was observed for overall reading times.

REREADING. Figure 3 shows rereading times in the experimental conditions. Inferential statistics for the rereading times are presented in Appendix B.

For every word of the sentence except for the first and last, there were main effects of gap type; rereading times for SRs were consistently shorter than those for ORs. Also, there was a significant interaction of gap type and head-noun type at the embedded verb ('invited-ADN'), the adverbial phase preceding it ('to the festival'), and the following head-noun position. At these three positions, the rereading-time differences between SRs and ORs were larger in the subject head-noun conditions than in the scrambled object head-noun conditions (Fig. 3, upper panel), while the conditions in which the object stayed in-situ showed no effect (Fig. 3, lower panel). Note that this pattern is once again similar to the patterns seen for overall reading times and for regression-path duration:
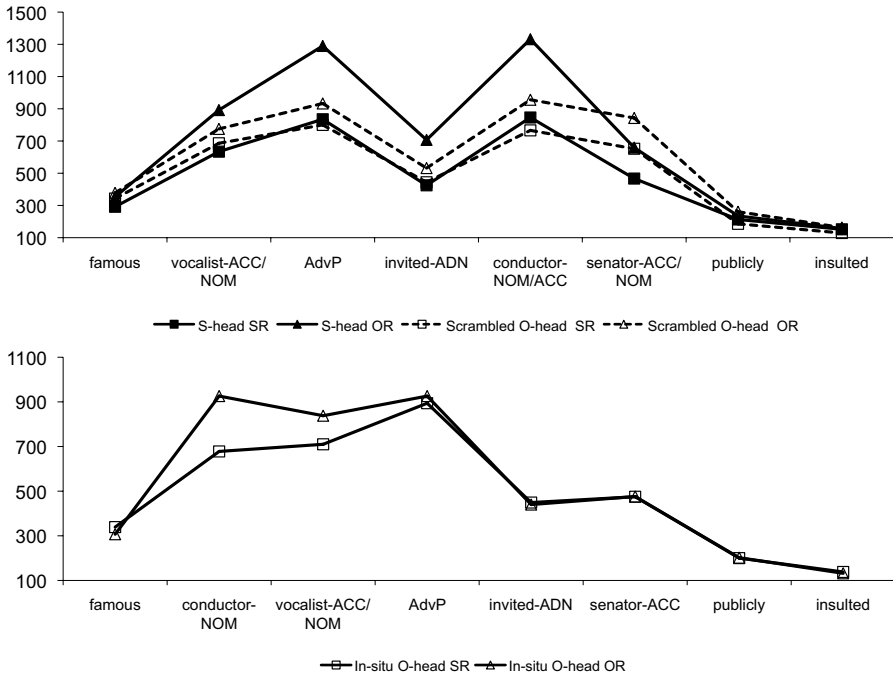
FIGURE 3. Rereading times of SRs and ORs across types of head noun of experiment 1.

subject head-noun conditions yield the most robust SR/OR asymmetries, scrambled object head-noun conditions yield asymmetries of intermediate size, and in-situ object head-noun conditions never show significant asymmetries.

A gap effect, however, was observed for the in-situ object head-noun conditions at the first (matrix) NP ('conductor-NOM') and the embedded NP ('vocalist-ACC/NOM'; lower panel). For these NPs, pairwise comparisons showed that rereading times for the initial (matrix subject) NP were significantly longer for ORs than SRs ($F1 = 12.48$, $MSE = 530,469$, $p < 0.001$; $F2 = 19.42$, $MSE = 336,712$, $p < 0.001$), with this difference being marginally significant at the second, embedded NP ($F1 = 4.26$, $MSE = 481,131$, $p < 0.05$; $F2 = 3.55$, $MSE = 589,520$, $p = 0.068$).

2.6. DISCUSSION. The overall results clearly showed that ORs took longer to read than SRs, primarily with subject head nouns and to a lesser extent with scrambled object head nouns, but not with object head nouns in situ. Below, we address the implications of these results for accounts based on linear/temporal distance (Gibson 2000, Lewis et al. 2006), structural complexity (O'Grady 1997), probabilistic structural disambiguation (Mitchell et al. 1995, Hale 2006), and similarity (Gordon et al. 2001, Lewis et al. 2006, Van Dyke & McElree 2006, Lee et al. 2007). To streamline the discussion, we address the results in terms of those theories that predict an OR advantage (linear and temporal distance), an SR advantage (structural complexity and probabilistic structural disambiguation), or crucial interactions of head noun and gap type (similarity).

LINEAR AND TEMPORAL DISTANCE: OR ADVANTAGE. In these accounts, the processing cost of a filler-gap dependency is defined in terms of the linear/temporal distance between the filler and gap (i.e. the gap postulation or missing argument reactivation position). These accounts predict an OR processing advantage or no processing advantage

at all. Neither prediction, however, was borne out by the experimental results: ORs always took longer to read in both early and later processing stages of sentence comprehension.

PHRASE-STRUCTURAL COMPLEXITY AND EXPERIENCE-BASED ACCOUNTS: SR ADVANTAGE. In an account based on phrase-structural complexity, processing difficulty associated with a filler-gap dependency is defined in terms of the hierarchical phrase-structural distance between the two linguistic elements in need of integration, namely filler and gap. Accordingly, this account predicts that the reading times for ORs in Korean should be longer than those for SRs because the structural distance between the gap position and the filler (head noun) is longer in ORs than in SRs. In experience-based models, by contrast, the initial parsing decision is influenced by structural frequency and the transitional structural ambiguity of an input sequence. Since ORs are less frequent (Kwon 2008) and have greater temporary structural ambiguity (Yun et al. 2010) than SRs, these models predict a processing advantage for SRs.

The results in general confirm these predictions. A subject/object processing asymmetry was evident primarily at later processing stages (as measured by regression-path duration and rereading times). This is generally consistent with previous eye-tracking experiments in English (Traxler et al. 2002, Gordon et al. 2006) and self-paced reading-time experiments in Korean (Kwon 2008). Surprisingly, however, we also found an early effect in the gaze duration (first-pass reading) measures, albeit only in the scrambled head-noun condition and not in the subject and in-situ object head-noun conditions (Fig. 2). Although previous eye-tracking studies of English have not found a comparable subject/object processing asymmetry in gaze duration, the significant effect of gap type in the scrambled object head-noun condition suggests that such an asymmetry could emerge even in very early stages of processing if working memory is more impacted. For example, this difference among the head-noun conditions could be due to the extra working-memory costs associated with scrambling (Ueno & Kluender 2003, Miyamoto 2006, Hagiwara et al. 2007) in the scrambled object head-noun conditions.

While the phrase-structural complexity hypothesis and experience-based models correctly predict the overall processing asymmetry of SRs and ORs in measures of early and late sentence comprehension, they do not account for the interaction between head noun and gap types found for those same measures. In particular, regression-path and rereading duration showed a subject/object processing asymmetry in the subject head noun and scrambled object head-noun conditions, but not in the in-situ object head-noun condition (except for the rereading of initial NPs); moreover, these measures showed that the processing asymmetry was much greater in the subject head-noun condition than in the scrambled object head-noun condition. These interactions can be accounted for in terms of similarity-based interference and main- vs. embedded-clause structural ambiguity.

CASE MARKERS AND NP SIMILARITY: INTERACTION OF HEAD NOUN AND GAP TYPE. In the similarity-based account, the processing difficulty of a filler-gap dependency is defined in terms of the similarity of two linguistic items that need to be represented in memory and retrieved for processing (Gordon et al. 2001, Lewis et al. 2006, Van Dyke & McElree 2006, Lee et al. 2007). This effect has been demonstrated using similar NP types in English (Gordon et al. 2001) and in Korean (Lee et al. 2007), and using similar case markers in Korean (Nakayama et al. 2005) and in Hindi (Vasishth 2003). In terms of processing a filler-gap dependency in Korean, a similarity-based account predicts an interaction between head noun and gap type. In our subject head-noun conditions, in

which the head noun was marked nominative, object RCs were predicted to cause a similarity effect on measures of later processing related to retrieval because the only overt NP remaining in the RC after object extraction was the subject, likewise marked nominative, thus leading to two successive NPs with nominative case marking. By the same token, in the scrambled object head-noun conditions, in which the head noun was marked accusative, subject RCs were predicted to trigger a retrieval-based similarity effect because the only overt NP remaining after subject extraction was the accusative-marked object, giving rise to two successive NPs with accusative case marking. The results showed, however, that ORs caused longer rereading times (a measure of later processing that plausibly reflects retrieval) in both the subject and scrambled object head-noun conditions. Thus, at first blush, it appears that the similarity-based interference account is not consistent with the results.

It should be noted, however, that there were significant interactions between head-noun type and gap type in the regression-path duration and rereading measures. That is, the subject/object processing asymmetry was much greater in subject head-noun conditions than in scrambled object head-noun conditions. This raises the possibility that increased processing difficulty due to successive NPs with the same case marking augmented the subject/object asymmetry triggered by phrase complexity and/or probabilistic structural disambiguation in subject head-noun constructions, but reduced the asymmetry in scrambled object head-noun constructions, for which SRs were predicted to be more difficult than ORs. This suggests that similarity effects and phrase-structural complexity effects and/or probabilistic structural disambiguation are not mutually exclusive, but rather that the similarity effect and the main effect triggered by phrase-structural complexity and/or probabilistic structural disambiguation were additive.[10] For RCs modifying object head nouns in situ, the similarity effect was restricted to rereading of the first two NPs of the sentence (matrix subject and embedded NP), and did not appear at the head noun. The effect observed in the rereading times of the first two NPs is consistent with Lee et al. 2007, while the absence of an effect at the head-noun position could be due to the embedded- vs. main-clause ambiguity discussed below.

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[10] A referee pointed out that the similarity-based interference hypothesis should also predict processing differences between SRs and ORs with different head-noun types: SRs would be expected to be more difficult in the scrambled object head-noun condition ($[_{RC\_\_i}$ NP-**ACC** V] head noun$_i$-**ACC**) than in the subject head-noun condition ($[_{RC}$ __$_i$ NP-**ACC** V] head noun$_i$-**NOM**), and ORs would be expected to be more difficult in the subject head condition ($[_{RC}$ NP-**NOM** __$_i$ V] head noun$_i$-**NOM**) than in the scrambled object head-noun condition ($[_{RC}$ NP-**NOM** __$_i$ V] head noun$_i$-**ACC**). As the referee noted, reading times were compatible only with the latter of these two predictions, leaving the similarity-based interference hypothesis only partially supported.

We believe, however, that a direct comparison between the subject head-noun conditions (head noun-NOM) and the object head-noun conditions (head noun-ACC) should be avoided for independent reasons. That is, it has been well established in previous studies that in languages with case markers such as Japanese and Korean, nominative-marked NPs incur higher processing costs than NPs with any other case markers. This slow-down at an NP-NOM has been attributed either to an intrinsic property associated with the nominative marker (e.g. exhaustive listing: Kuno 1973, Yamashita 1997) or to a clause-boundary effect cued by the nominative marker (Uehara 1997, Yamashita 1997, Miyamoto 2002). Moreover, the accusative-marked head noun of a sentence-initial RC involves either scrambled word order, as in the current experiment, or subject drop, which might also increase the processing load. For all these reasons, attempting to compare reading times across head-noun types would involve too many confounding factors, and the reading-time differences between subject head-noun (NP-NOM) and object head-noun (NP-ACC) conditions should therefore not be taken as a critical argument for or against the similarity-based interference hypothesis. In this article we thus restrict our comparison to head nouns of the same type.

EMBEDDED- VS. MAIN-CLAUSE STRUCTURAL AMBIGUITY. The absence of a subject/ object asymmetry in the in-situ object head-noun conditions could be due to garden-path effects. In head-final languages, there is no overt marking of the left boundary of a clause since subordinators do not appear until the end of the clause. This means that in SRs modifying in-situ object head nouns (9), the remaining NP-ACC after subject extraction could initially be processed as the object of the main clause, following as it does immediately on the heels of the main-clause subject. This initial parse needs to be revised at the head-noun position. By contrast, ORs modifying in-situ object head nouns do not create an embedded- vs. main-clause structural ambiguity, since the relative-clause subject NP-NOM signals a clause boundary (Miyamoto 2002). Thus at the head-noun position, processing costs associated with garden-path reanalysis in SRs (22) and processing costs associated with subject preference and similarity in ORs (23) may have canceled each other out, yielding no processing asymmetry between SRs and ORs.

It is not clear, however, why garden-path SRs with in-situ object head nouns did not show any processing difficulty compared to SRs with other head-noun types, and, in fact, were processed even faster than other SRs despite this garden-path confound. More generally, it is not clear why SRs and ORs with in-situ O-head nouns were both processed faster than their counterparts with other types of head nouns. We leave this as a topic for future investigation.

In summary, the results of experiment 1 are consistent with accounts based on phrase-structural complexity, probabilistic structural disambiguation, and NP similarity, and suggest that similarity effects and the effects triggered by phrase-structural complexity and/or probabilistic structural disambiguation are additive. There remain some outstanding unresolved issues with regard to in-situ O-head constructions, which showed very little processing asymmetry between SRs and ORs. When they did, however, it was in the direction predicted by phrase-structural complexity and probabilistic structural disambiguation. Moreover, results from the in-situ object head-noun conditions suggest the presence of a strong garden-path effect in SRs (22) due to an inherent embedded- vs. main-clause structural ambiguity, likely canceling out any effects associated with similarity or phrase-structural complexity/probability expectation in ORs (23). The experimental results were in any case not consistent with predictions of linear and temporal distance accounts.

3. EXPERIMENT 2. The overall results of the first experiment support accounts based on phrase-structural complexity (O'Grady 1997), probabilistic structural disambiguation (Mitchell et al. 1995, Hale 2006), and similarity-based interference (Gordon et al. 2001, Lewis et al. 2006, Van Dyke & McElree 2006, Lee et al. 2007), but not accounts based on linear/temporal distance (Gibson 2000, Lewis et al. 2006). Still, the absence of a linear/temporal-distance effect could be due to a structural ambiguity inherent in Korean (and possibly in Japanese as well). Although gaps in RCs and *pro* exhibit somewhat similar processing profiles (Kwon 2008), this structural ambiguity has consequences for the calculation of the linear/temporal distance between a gap and its filler. Given the ubiquitous occurrence of argument drop in Korean (subject: 69.4%, object: 52.8%, Y. Kim 2000), upon encountering a missing argument, the parser is likely to interpret the gap position as *pro* rather than as a relative-clause gap. If so, since a filler (head noun) is obligatory only for a relative-clause gap but not for *pro*, this structural ambiguity could be responsible for the absence of effects of linear/temporal distance between gap and filler in experiment 1.

In a previous self-paced reading-time study on the comprehension of Japanese, Ishizuka and colleagues (2006) argued that the longer reading times of ORs in earlier ex-

periments (Ishizuka et al. 2003, Miyamoto & Nakamura 2003) were due to the greater temporary structural ambiguity of ORs vs. SRs: Japanese ORs, with a sentence-initial NP-NOM, are more likely to be interpreted as monoclausal than SRs, with a noncanonical sentence-initial NP-ACC.[11] Ishizuka et al. 2006 further argued that without the confound of structural ambiguity, SRs should be more difficult to process than ORs due to greater linear distance between filler and gap. To test this hypothesis, preceding context was used to force a relative-clause reading of their stimulus materials. The self-paced reading-time results showed that SRs took longer to read than ORs, as predicted, though the effect was significant at the embedded predicate ('interviewed' in example 27 below) and not at the head-noun position. The results were taken as evidence for linear distance as a major constraint on processing gap-filler as well as filler-gap dependencies.

[AQ3]

> (27) Materials used in Ishizuka et al. 2006
>
> Preceding context: A reporter interviewed a writer on a TV program. Then the writer interviewed another reporter for his new novel.
>
> Taro: 'Which reporter stands [is standing] as a candidate for [in] the election?'
>
> Hanako: SR: [___$_i$ writer-ACC interviewed] reporter$_i$ was it seems
> 'It seems to be the reporter who interviewed the writer.'
> OR: [writer-NOM ___$_i$ interviewed] reporter$_i$ was it seems
> 'It seems to be the reporter who the writer interviewed.'

The results are questionable for several reasons, however. First, longer reading times for SRs at the embedded predicate position could be due to a spillover effect from the immediately preceding sentence-initial NP-ACC, given that a sentence-initial NP-ACC has been shown to be followed by a slowdown one word later in self-paced reading times both in Japanese and Korean (Japanese: Miyamoto & Nakamura 2003, Ueno & Garnsey 2008; Korean: Kwon 2008). This interpretation is buttressed by the fact that the slowdown in SRs was present only at the embedded predicate, but not at the following head-noun position. Alternatively, longer reading times at the embedded predicate in SRs could be due to the fact that their contexts are based on the first sentence of the preceding discourse context, which is more prone to memory decay, while the OR condition is based on the second sentence of the preceding context, which is by hypothesis more active in working memory. These alternative accounts weaken the interpretation of the experimental results in Ishizuka et al. 2006 as providing crucial support for the role of linear distance in processing prenominal relative clauses. Thus, it is important to replicate and confirm Ishizuka and colleagues's finding using on-line measures in a language like Korean with similar grammatical features to those of Japanese.[12]

In experiment 2, we tested linear and temporal distance accounts controlling for the confounds discussed above. There were four conditions, varying gap type (SR vs. OR)—but not head-noun type as in experiment 1—and preceding context (with and without preceding context). Following Ishizuka et al. 2006, context was given in the form of a conversation between two people: it introduced a sentence describing two in-

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[11] Mieko Ueno (p.c.) suggests that ORs in Japanese are not particularly more ambiguous than SRs. According to the sentence-completion study results in Ueno & Garnsey 2008, monoclausal sentences with subject drop were frequently produced even when there was no discourse context, suggesting that both subject and object RCs are subject to structural ambiguity (i.e. conflicting initial interpretations as a monoclausal sentence with argument drop vs. a relative clause).

[12] Ishizuka and her colleagues, in fact, did not replicate the OR processing advantage in their two follow-up experiments: in the first experiment, they found no reliable difference between SR and OR, and in the second, they found an SR processing advantage (Ted Gibson, p.c.).

dividuals involved in different events.[13] The target relative clause was based on the information provided by this context.

[AQ4]

(28) Context for SR
    Minji: Two chancellors are being investigated.
        [EVENT1 The first chancellor, he threatened the editor for taking a bribe], and [EVENT2 the other chancellor, he threatened the editor for embezzling public funds].
    Swuni: I heard that according to the police report, one of the chancellors had met a journalist. Which chancellor met the journalist?

(29) SR target construction
    [__$_i$ sinmwunsa-uy pyencipcang-ul noymwul swuswu hyemuy-lo
    __ newspaper-GEN editor-ACC   bribe   taking suspicion-with
    hyeppakha-n] chongcang$_i$-i enlonin-ul   mann-ass-ta
    threaten-ADN] chancellor-NOM journalist-ACC meet-PST-DECL
      'The chancellor [who __ threatened the editor for taking a bribe] met the journalist.'

(30) Context for OR
    Minji: Two chancellors are being investigated.
        [EVENT1 The first chancellor, the editor threatened him for taking a bribe], and [EVENT2 the other chancellor, the editor threatened him for embezzling public funds].
    Swuni: I heard that according to the police report, one of the chancellors had met a journalist. Which chancellor met the journalist?

(31) OR target construction
    [sinmwunsa-uy pyencipcang-i __$_i$ noymwul swuswu hyemuy-lo
    newspaper-GEN editor-NOM   __ bribe   taking suspicion-with
    hyeppakha-n] chongcang$_i$ –i enlonin-ul   mann-ass-ta
    threaten-ADN] chancellor-NOM journalist-ACC meet-PST-DECL
      'The chancellor [who the editor threatened __ for taking a bribe] met the journalist.'

(32) Question format 1: [NP-NOM NP-ACC Verb]
    enu   chongcang-i   enlonin-ul   mann-ass-sup-ni-kka?
    which chancellor-NOM journalist-ACC meet-PST-HON-IND-Q?
      'Which chancellor met the journalist?'

(33) Question format 2: [NP-ACC NP-NOM Verb]
    enlonin-ul   enu   chongcang-i   mann-ass-sup-ni-kka?
    journalist-ACC which chancellor-NOM meet-PST-HON-IND-Q?
      'Which chancellor met the journalist?'

To control for the apparent processing cost associated with a sentence-initial NP-ACC, an adverbial phrase (e.g. 'for taking a bribe' in 29) was inserted between the NP-ACC and the embedded predicate position. In addition, the order of presentation of events related to the experimental sentences was counterbalanced: half of the experimental sentences in both the subject and object RC conditions were based on the first event, while the other half were based on the second event. The word order of the question was also controlled to prevent a possible syntactic priming effect (Bock 1986, Pickering &

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[13] The format of the context was slightly modified from the format in Ishizuka et al. 2006 to promote a natural reading in Korean.

Branigan 1998, Hartsuiker & Westenberg 2000), given that SRs start with NP-ACC while ORs start with NP-NOM. Half of the questions had the word order of NP-NOM NP-ACC Verb, while the other half had NP-ACC NP-NOM Verb word order, as shown in 32 and 33. These factors were controlled across subject and object RC conditions. The experimental conditions also included corresponding subject and object RC experimental sentences without preceding context for a direct comparison between conditions with and without context.

If the slowdown observed in ORs in previous studies is due to the greater structural ambiguity of ORs in comparison to SRs, and if linear/temporal distance between filler and gap is a major processing constraint in prenominal RCs, as argued in Ishizuka et al. 2006, then there should be an interaction of gap type with context. That is, when there is no preceding context, ORs should take longer to process than SRs at the head-noun position where filler and gap are integrated; when there is preceding context, the asymmetry pattern should be reversed, with SRs exhibiting longer times than ORs, or there should be no processing asymmetry. However, if phrase-structural complexity and/or probabilistic structural disambiguation but not linear/temporal distance impose a major constraint on the processing of prenominal RCs, as suggested by experiment 1, there should be no crossover interaction of gap type and context, and ORs should show more processing difficulty than SRs at the head-noun position regardless of the presence or absence of context.

3.1. PARTICIPANTS. Thirty-six native speakers of Korean at Korea University served as participants in the experiment. They received credit in an introductory psychology course for their participation. All had normal or corrected-to-normal vision.

3.2. MATERIALS AND DESIGN. Thirty-two sets of four experimental conditions constructed as in 29 and 31 (SR and OR, with and without context) in which the plausibility of SR vs. OR readings was controlled were taken from Kwon 2008 (see n. 8). These experimental sentences were distributed over four lists in a Latin square design, such that participants saw only one condition out of four in each experimental stimulus set.

3.3. EYE-TRACKING MEASURES AND PROCEDURE. The eye-tracking measures and procedures were the same as in experiment 1. Short fixations made up 2.2% of total fixations; 0.8% were deleted and 1.4% were combined with the adjacent fixation. Fixations longer than 800 ms were trimmed to 800 ms (0.2% of total fixations).

Each trial started with a fixation point '*' and ended with a comprehension question. For stimulus sentences with context, the context was shown on the screen as a conversation between two people. Participants were instructed to press the space bar on the keyboard after they had finished reading the context sentences. The target sentence then appeared, after which participants pressed the space bar to see a true/false comprehension statement. True and false statements were distributed equally across the conditions, and all the comprehension questions focused on the content of the relative clause. Participants responded by pressing '/' for true and 'z' for false. For sentences without context, the experimental procedures were the same as in experiment 1. There were six practice trials.

3.4. RESULTS. As seen in Table 3, comprehension accuracy scores were higher for SRs than for ORs ($F1(1,35) = 16.25$, $MSE = .16$, $p < 0.001$; $F2(1,31) = 3.95$, $MSE = .04$, $p < 0.056$). Overall reading times of the experimental sentences showed main effects of gap (relative clause) type ($F1(1,35) = 23.75$, $MSE = 9,818,758$, $p < 0.001$; $F2(1,31) = 15.85$, $MSE = 14,714,112$, $p < 0.001$) and of context ($F1(1,35) = 53.22$, $MSE = $

32,669,426, $p < 0.001$; $F2(1,31) = 101.36$, $MSE = 17,153,843$, $p < 0.001$). Reading times were shorter for SRs than for ORs. Also, reading times were shorter when there was preceding context.

| | GAP TYPE | | DIFFERENCE |
	SR	OR	OR – SR
context	.75	.64	–.11
	6071	6732	661
no context	.73	.67	–.06
	8289	9428	1139

TABLE 3. Comprehension accuracy and overall reading times in experiment 2.

GAZE DURATION. Figure 4 shows gaze durations in the experimental conditions. Inferential statistics for the gaze durations are presented in Appendix B. In all regions except for the very last word, there were significant main effects of context. Gaze durations in these regions were significantly shorter when there was preceding context. There was no effect of gap type in any region, however.
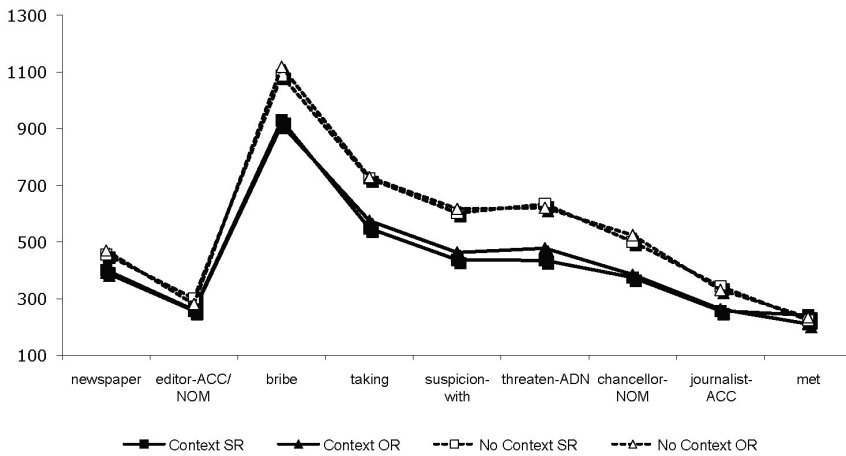
FIGURE 4. Gaze duration of SRs and ORs with and without context of experiment 2.

REGRESSION-PATH DURATION. Table 4 shows the regression-path duration of SRs and ORs with and without context. Inferential statistics for regression-path duration are presented in Appendix B. Regression-path durations were calculated for the embedded verb and head-noun regions, as well as for the main-clause object region occurring immediately after the head noun.

| | GAP TYPE | W6 | W7 | W8 |
		threaten-ADN	chancellor-NOM	journalist-ACC
context	SR	651	843	1161
	OR	792	1080	1652
no context	SR	810	974	1191
	OR	880	1218	1682

TABLE 4. Regression-path durations in experiment 2.

Regression-path duration of all three regions showed significant effects of gap type: the regression-path duration for ORs was longer than for SRs. Also, regression-path du-

rations were shorter in the embedded verb (W6) and head-noun regions (W7) when there was preceding context.

REREADING TIMES. The rereading times of the four conditions are presented in Figure 5 and the inferential statistics for the rereading times are presented in Appendix B.
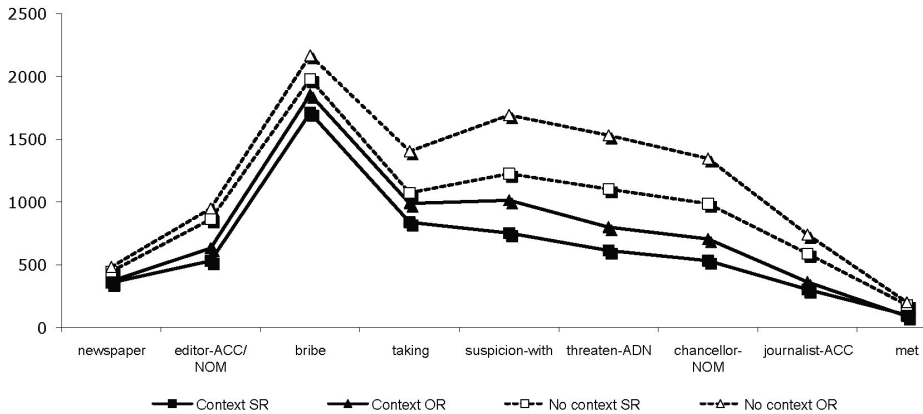

FIGURE 5. Rereading times of SRs and ORs with and without context of experiment 2.

In every region, rereading times were shorter with preceding context. Also, the rereading times were shorter in SRs than in ORs from the second word of the sentence to the second-to-last word of the sentence (W2 to W8). In the embedded verb region (W6), there was a significant interaction between gap type and context ($F1(1,35) = 6.32$, $MSE = 672,230$, $p < 0.05$; $F2(1,31) = 4.16$, $MSE = 1,021,753$, $p < 0.05$). This interaction was due to the smaller subject/object asymmetry when there was preceding context compared to when there was no context.

3.5. DISCUSSION. Overall, the results clearly showed that ORs took longer to read than SRs both with and without the use of preceding context, consistent with the results reported in experiment 1.

Recall that the linear- and temporal-distance accounts predict a crossover interaction of gap type and context: when there was preceding discourse context, SRs were either predicted to take longer to read than ORs (due to greater linear/temporal filler-gap distance), or no processing asymmetry at all was predicted (due to identical linear/temporal distance between the RC verb and the head noun); when there was no preceding discourse, ORs were predicted to take longer to read than SRs due to greater structural ambiguity (Ishizuka et al. 2006). By contrast, the phrase-structural and experience-based accounts predicted that ORs would take longer to read than SRs regardless of the use of the context, and thus no crossover interaction of gap type and context was predicted.

The rereading-time results did show an interaction at the embedded verb. This effect, however, was different from that predicted by linear and temporal gap-filler distance accounts: ORs took longer to read than SRs both with and without context. The observed interaction was simply due to the smaller asymmetry when there was preceding context than when there was no preceding context. Although the smaller asymmetry in rereading times at the embedded predicate with context than without could be due to the effect of context on comprehension, this interaction does not provide support for linear or temporal distance. This indicates that even when structural ambiguity is removed by

forcing the RC reading, linear- and temporal-distance accounts do not act as a major constraint on the processing of prenominal RCs in Korean. Instead, these results are again consistent with phrase-structural complexity and experience-based accounts.

In relation to the experimental results reported in Ishizuka et al. 2006, although the use of a different methodology (eye-tracking in the current experiment vs. self-paced reading time in Ishizuka et al. 2006) does not allow direct comparison between the two studies, our experimental results showed that the gaze duration in the SR condition was slightly longer than in the OR condition right after the NP-ACC in the RC, although the difference was minimal, with no statistical significance (929 vs. 913 ms, $p > 0.55$). This suggests that the slowdown in subject RCs in Ishizuka et al. 2006 could have been due to a spillover effect from the immediately preceding NP-ACC.

In summary, the overall results provide additional support for the phrase-structural complexity and experience-based accounts. The results, however, were not consistent with linear- and temporal-distance accounts either with or without preceding context.

4. GENERAL DISCUSSION. In experiment 1, we investigated the processing of SRs and ORs without context across different types of head nouns, including subject, in-situ object, and scrambled object head nouns. The results were consistent with the predictions of accounts based on phrase-structural complexity, probabilistic structural disambiguation, and similarity-based interference, but not with those of linear- and temporal-distance accounts (Gibson 1998, Lewis et al. 2006). Since the role of linear and temporal distance in processing gap-filler dependencies in prenominal relative clauses might not be fairly evaluated in the presence of structural ambiguity (Ishizuka et al. 2006), however, experiment 2 used discourse context to remove this confound by promoting a relative-clause reading. The results were still inconsistent with the predictions of linear and temporal accounts, but consistent with those of phrase-structural and experience-based accounts, in that ORs were more difficult to process than SRs regardless of the presence or absence of context.

In evaluating the implications of these findings, we address linear- and temporal-distance accounts before turning to phrase-structural complexity and its relation to the accessibility hierarchy. Discussion of the similarity-based interference and experience-based accounts follows that.

Although linear- and temporal-distance accounts are consistent with the experimental results in languages with postnominal RCs, they are not consistent with the present experimental results. One possible source of the difference could be the relative order of filler and gap. In filler-gap ordering, the filler needs to be stored in working memory in expectation of a gap: retaining semantic and/or phonetic information associated with the filler until the gap is encountered while processing additional sentence material occurring between the two requires additional working-memory resources. Thus the longer the distance between filler and gap, the greater the processing load (Gibson 1998, 2000). Alternatively, filler retrieval may be more prone to memory decay with longer temporal distance between filler and gap (Lewis & Vasishth 2005).

By analogy, one might expect gap-filler dependencies to require storage of the gap (i.e. holding a slot open) in working memory and retrieval of that open slot when encountering an appropriate filler. The gap is not stored in memory, however, because it does not yet have a phonetic value. Moreover, thematic information associated with a gap does not come from the gap itself, but rather from the embedded subcategorizing verb both in SRs (15) and ORs (16); referential information associated with a gap comes from the head noun. On this view, storing or reactivating a potential gap (i.e. a

missing argument slot) in working memory may not cause processing difficulty and hence produce no linear/temporal-distance effect.

Alternatively, the processing of prenominal relative clauses might not have anything to do with gap postulation or storage of a potential gap in working memory. Instead, the head noun may be directly associated with the RC verb that occurs immediately before it in both SRs and ORs, or even with the relative clause as a whole. Although typical relative clauses in Korean show different syntactic distributions and properties from noun modifying clauses (e.g. [NP [CP *fish-NOM burn-ADN*] *smell*] 'smell of fish burning') (J. Kim 1998, Lee 2004, Kwon 2008), we cannot exclude the possibility that relative clauses could be processed in a manner similar to noun-modifying clauses as sentential modifiers that are licensed by their semantic/pragmatic relation with the head noun (cf. Matsumoto 1997, Comrie 1998). These possibilities, however, all suggest that linear/temporal distance may not be an important factor in processing prenominal RCs in Korean (and possibly in Japanese as well).

The results do provide solid evidence for the role of phrase-structural complexity in sentence processing: longer phrase-structural gap-filler distance leads to greater processing difficulty, both with and without context. Therefore, the current results—in conjunction with results from languages with postnominal RCs—suggest that phrase-structural complexity is a universal processing constraint on sentence comprehension (see Ueno & Garnsey 2008 for a similar conclusion related to Japanese). It should be noted, however, that the actual source of the processing difficulty in this account remains unclear. Although processing difficulty could be defined simply as the phrase-structural distance between filler and gap, as suggested in O'Grady 1997, the results do not exclude the possibility that postulation of a gap in a deeper structural position itself is the source of difficulty, regardless of the structural position of the filler. That is, object relative-clause sentences could be harder to process than subject relative-clause sentences because the object gap is structurally more deeply embedded than the subject gap, and not because the structural distance between the object gap and the filler is longer than the distance between the subject gap and the filler.[14] In the sense that phrase-structural complexity can be defined in terms of the structural position of the gap itself rather than in terms of the distance between a gap and its filler, the accessibility hierarchy and the phrase-structural distance hypothesis could be taken as notational variants of each other. If this is the case, this may prove to be a welcome result that could bridge the gap between functional-typological and generative approaches to grammar.

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[14] If depth of embedding of the gap is the decisive factor in determining processing costs, a referee asked why the slowdown was found at the filler position and pointed out that the 'peculiarity' of the processing profile of a gap should originate from the fact that its identity is relative to its antecedent or filler. We agree with the referee that a gap and filler have a close relationship with each other (hence, filler-gap dependency) but do not think that the slowdown at the head noun necessarily suggests that the processing difficulty of a gap should always be stated in terms of its filler. At the head-noun position, a gap (missing argument slot) needs to be retrieved for purposes of association with the filler, and thus the slowdown at the head noun could be taken to indicate that the more difficult it is to retrieve the gap (missing argument slot) from preceding, already processed material, the more difficult the integration process will be. In addition, by formulating the processing costs of a gap independent of its filler or antecedent, we can also predict the processing difficulty of a gap without an intra-sentential filler or antecedent. For example, in a language with argument-drop, we would predict that 'I met __ in the park' will be harder to process than ' __ met him in the park' because the gap is more deeply embedded in the first sentence. There are at present no empirical data to support this prediction, but we believe that this is a testable hypothesis for future research.

The role of language universals and crosslinguistic variation has long been at the center of attention of these two different approaches (Polinsky & Kluender 2007). In one approach, represented by Greenberg (1963) and subsequent work inspired by his, a wide range of languages are examined, and language universals are typically described in terms of interrelations among different linguistic properties. The accessibility hierarchy is a well-known product of this typological approach, and has even been proposed as an absolute universal (Keenan & Comrie 1977; see Comrie 1989:155 for a discussion of the scope of relevant linguistic structure in defining absolute universals vs. tendencies). By contrast, the phrase-structural distance hypothesis was developed within a more formal, generative approach, in which language universals are investigated in terms of abstract representations that underlie the surface variation found across languages (Chomsky 1957). Although seemingly quite different, these two approaches are actually quite similar: both assume a close relation between linguistic knowledge and language processing (Keenan & Comrie 1977, Bresnan & Kaplan 1982, Berwick & Weinberg 1984). Thus the convergence of these different views of the nature of language universals suggests that the subject/object processing asymmetry is an inherent language universal predicted by both typological and generative analyses of crosslinguistic variation.

Furthermore, the possibility of reinterpreting the accessibility hierarchy in phrase-structural terms allows for greater insight into its inherent nature. The ACCESSIBILITY HIERARCHY as a crosslinguistic generalization on relative-clause formation was originally accounted for in terms of processing (Keenan & Comrie 1977, Keenan & Hawkins 1987): relative-clause types in higher positions on the hierarchy are more common crosslinguistically because they are easier to process. Attributing the subject/object processing asymmetry to the accessibility hierarchy is therefore a circular argument. But by redefining the accessibility hierarchy in independently motivated phrase-structural terms, it is possible to conceive of it as emerging from the complexity of the mental representation of a structure (see Hawkins 1994, Hale 2006).

We have pointed out that both the accessibility hierarchy and phrase-structural distance can account for the subject vs. object preference found in our study. The two hypotheses, however, would seem to make different predictions for indirect vs. direct object relative clauses in Korean. The accessibility hierarchy claims that relative clauses modifying indirect objects should be less common than direct-object relative clauses crosslinguistically, and implies that their processing should also be more difficult. By contrast, for languages like Korean, in which the indirect object is typically higher in the phrase-structure tree than the direct object (Park & Whitman 2003), the phrase-structural distance hypothesis predicts that indirect object–modifying relative clauses should be easier to process than direct object–modifying relative clauses. Thus, in order to decide between these two competing hypotheses, one would need to investigate the processing of indirect vs. direct object relative clauses in Korean.

The results also offer some evidence in support of similarity-based interference. Similarity-based interference has been characterized as occurring at the time of retrieval, such that selection of correct items is more difficult when similar items are being held in working memory. In the current study, the similarity of case markers on the NP within the relative clause and on the head noun led to processing difficulty, in accordance with the similarity-based interference account. At first blush, given that the head noun only needs to be associated with the thematic and argument information of the gap processed at the immediately preceding embedded predicate, the similarity interference effect of the case marker on the remaining NP within the relative clause seems puzzling.

It should be noted, however, that in Korean verbs do not agree with their arguments, and thus, without the remaining NP, the role of the gap remains ambiguous (Hawkins 2004). This means that the thematic and argument information of the gap comes from two sources: the embedded verb and the remaining NP within the relative clause. That is, embedded verbs carry information about thematic and argument structure, and the remaining NP within the relative clause distinguishes the role of the gap. This suggests that when the thematic and argument information for a gap is associated with the head noun, the remaining NP within the relative clause is active in working memory as well, leading to a similarity effect of case markers on the NPs within the relative clause and the head noun. Overall, the results suggest that effects of similarity are not limited to NP type but can also be extended to structural information, as encoded by case markers (Van Dyke & Lewis 2003, Vasishth 2003, Nakayama et al. 2005).

The results are also consistent with the predictions of experience-based models, according to which more frequent constructions are more familiar and are thus processed with less difficulty. It should be noted, however, that accounts like the tuning hypothesis based purely on frequency suffer from the same inherent circularity as the accessibility hierarchy: is a certain construction more frequent because it is easier to process or is the construction easier to process because it is more frequent? Although the entropy-reduction hypothesis (Hale 2006) also makes reference to frequency, it avoids this circularity in that it also makes crucial reference to phrase-structural representations. This nicely mirrors the compatibility of the accessibility hierarchy with phrase-structural complexity, as discussed above.

We do not have evidence that distinguishes between linguistically motivated accounts (i.e. the accessibility hierarchy and the phrase-structural distance hypothesis) and experience-based processing facilitation in our study. Although these accounts are not mutually exclusive and may all turn out to be important factors in the processing of prenominal relative clauses, future research needs to be conducted to distinguish which effects are caused by which factors.

Finally, it is worth comparing experimental results in Japanese, Korean, and Chinese. In Japanese and Korean, both strictly head-final languages, the one Japanese study (Ishizuka et al. 2006) claiming an OR advantage with appropriate context was not replicated for Korean in the current study; moreover, it has not even been replicated by Ishizuka and colleagues (see n. 12). Chinese, by contrast, presents a mixed picture in terms of both typology and experimental results as a head-initial language with head-final relative clauses. In some studies, SRs in Chinese have been found to have a processing advantage (C. Lin & Bever 2006, C. Lin 2006, 2008, Kuo & Vasishth 2006), whereas other studies claim that SRs incur processing costs (Hsiao & Gibson 2003, Y. Lin & Garnsey 2007, Gibson & Wu 2010). While the jury is still out on the processing status of relative clauses in Chinese, systematic comparison of processing results from a wide range of typological groups of languages should help to provide further clarity with regard to the language-universal vs. language-particular nature of parsing strategies.

5. CONCLUSIONS. Our experimental results show that object relative clauses are more difficult to process than subject relatives in Korean. This effect was significant when a gap was temporarily ambiguous as either a constituent of a relative clause or a dropped argument, and also when preceding context reduced such ambiguity by promoting a relative-clause reading. We have discussed these results in terms of the nature of gaps, defined either in terms of the hierarchy of grammatical relations (i.e. the accessibility hierarchy) or hierarchical phrase structure (i.e. the degree of embedding in a clause

structure, as in the phrase-structural distance hypothesis). While the present data do not distinguish between these two accounts, these accounts make opposite testable predictions for the relative difficulty of direct- vs. indirect-object relative clauses in Korean—an object of further study. Our results were also consistent with the predictions of experience-based models, but not with those of linear/temporal-distance accounts. In terms of similarity-based interference, our results suggest that similarity-based interference is not limited to NP types but can also be extended to instances of structural similarity.

<div align="center">APPENDIX A: SAMPLE SENTENCES[15]</div>

EXPERIMENT 1

1-a/b: SR/OR with subject head noun

[sengsilhan kyengchalkwan-**ul/i** elum nakksi kwumeng-eyse kwuhaynay-n] cippaywon-i   yaksa-lul
 diligent   policeman-**ACC/NOM** ice fishing hole-from   save-ADN   mailman-NOM pharmacist-ACC
    ilccikpwuthe chacawass-ta
      early   came.to.meet-DECL

  SR: 'The mailman who saved the diligent policeman from an ice fishing hole came to meet a pharmacist early in the morning.'

  OR: 'The mailman who the diligent policeman saved from an ice fishing hole came to meet a pharmacist early in the morning.'

1-c/d: SR/OR with object head noun

sengsilhan cippaywon-i [kyengchalkwan-**ul/i** elum nakksi kwumeng-eyse kwuhaynay-n] yaksa-lul
diligent   mailman-NOM policeman-**ACC/NOM** ice fishing hole-from   save-ADN   pharmacist-ACC
    ilccikpwuthe chacawass-ta
      early   came.to.meet-DECL

  SR: 'The diligent mailman came to meet the pharmacist early in the morning who saved the policeman from an ice fishing hole.'

  OR: 'The diligent mailman came to meet the pharmacist early in the morning who the policeman saved from an ice fishing hole.'

1-e/f: SR/OR with scrambled object head

[sengsilhan kyengchalkwan-**ul/i** elum nakksi kwumeng-eyse kwuhaynay-n] cippaywon-ul yaksa-ka
 diligent   policeman-**ACC/NOM** ice fishing hole-from   save-ADN   mailman-ACC pharmacist-NOM
    ilccikpwuthe chacawass-ta
      early   came.to.meet-DECL

  SR: 'The pharmacist came to see the mailman early in the morning who saved the diligent policeman from an ice fishing hole.'

  OR: 'The pharmacist came to see the mailman early in the morning who the diligent policeman saved from an ice fishing hole.'

2-a/b: SR/OR with subject head

[yumenghan ceycakca-**lul/ka**   kongkal saki hyemuy-lo   wuyhyepha-n] yenchwulca-ka
 famous   producer-**ACC/NOM** a con trick   suspicion-for threaten-ADN   director-NOM
    kamtok-ul   taytanhi mwusihayss-ta
    filming.director-ACC very   ignored-DECL

  SR: 'The director who threatened the famous producer about a con trick fully ignored the filming director.'

  OR: 'The director who the famous producer threatened about a con trick fully ignored the filming director.'

2-c/d: SR/OR with object head

yumenghan yenchwulca-ka [ceycakca-**lul/ka**   kongkal saki hyemuy-lo   wuyhyepha-n]
famous   director-NOM   producer-**ACC/NOM** a con trick   suspicion-for threaten-ADN
    kamtok-ul   taytanhi mwusihayss-ta
    filming.director-ACC very   ignored-DECL

  SR: 'A famous director fully ignored the filming director who threatened the producer about a con trick.'

  OR: 'A famous director fully ignored the filming director who the producer threatened about a con trick.'

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[15] A complete list of experimental sentences is available upon request.

2-e/f: SR/OR with scrambled head

[yumenghan ceycakca-**lul/ka**   kongkal saki hyemuy-lo   wuyhyepha-n] yenchwulca-lul
 famous   producer-**ACC/NOM** a con trick   suspicion-for threaten-ADN   director-ACC
     kamtok-i   taytanhi mwusihayss-ta
     filming.director-NOM very   ignored-DECL
   SR: 'A filming director fully ignored the director who threatened the famous producer about a con trick.'
   OR: 'A filming director fully ignored the director who the famous producer threatened about a con trick.'

3-a/b: SR/OR with subject head

[chenglyemhan pwuuycang-**ul/i**   cengchi picakum hyumuy-lo   pipangha-n] isacang-i
 honest   vice.chair-**ACC/NOM** politics slush.fund suspicion-with criticize-ADN executive-NOM
     hoycang-ul   cenphokcekulo cicihayss-ta
     president-ACC completely   supported-DECL
   SR: 'The executive who criticized the honest vice chair about the political slush fund fully supported the
         president.'
   OR: 'The executive who the honest vice chair criticized about the political slush fund fully supported the
         president.'

3-c/d: SR/OR with object head

chenglyemhan isacang-i   [pwuuycang-**ul/i**   cengchi picakum hyumuy-lo   pipangha-n]
honest   executive-NOM vice.chair-**ACC/NOM** politics slush.fund suspicion-with criticize-ADN
     hoycang-ul   cenphokcekulo cicihayss-ta
     president-ACC completely   supported-DECL
   SR: 'The honest executive fully supported the president who criticized the vice chair about political slush
         fund.'
   OR: 'The honest executive fully supported the president who the vice chair criticized about political slush
         fund.'

3-e/f: SR/OR with scrambled object head

[chenglyemhan pwuuycang-**ul/i**   cengchi picakum hyumuy-lo   pipangha-n] isacang-ul
 honest   vice.chair-**ACC/NOM** politics slush.fund suspicion-with criticize-ADN executive-ACC
     hoycang-i   cenphokcekulo cicihayss-ta
     president-NOM completely   supported-DECL
   SR: 'The president fully supported the executive who criticized the honest vice chair about the political
         slush fund.'
   OR: 'The president fully supported the executive who the honest vice chair criticized about the political
         slush fund.'

4-a/b: SR/OR with subject head

[pwuyuhan unhayngwon-**ul/i** tongney ssilum tayhoy-eyse   ungwonha-n] kenmwulcwu-ka swunkyeng-ul
 wealthy   banker-**ACC/NOM** town   *ssilum* competition-at rooted.for-ADN landlord-NOM   policeman-ACC
     maywu silhehayss-ta
     very   dislike-DECL
   SR: 'The landlord who rooted for the wealthy banker at the town *ssilum* competition disliked the police-
         man a lot.'
   OR: 'The landlord who the wealthy banker rooted for at the town *ssilum* competition disliked the police-
         man a lot.'

4-c/d: SR/OR with object head

pwuyuhan kenmwulcwu-ka [unhayngwon-**ul/i** tongney ssilum tayhoy-eyse   ungwonha-n]
wealthy   landlord-NOM   banker-**ACC/NOM** town   *ssilum* competition-at rooted.for-ADN
     swunkyeng-ul maywu silhehayss-ta
     policeman-ACC very   dislike-DECL
   SR: 'The wealthy landlord disliked the policeman a lot who rooted for the banker at the town *ssilum* com-
         petition.'
   OR: 'The wealthy landlord disliked the policeman a lot who the banker rooted for at the town *ssilum* com-
         petition.'

4-e/f: SR/OR with scrambled object head

[pwuyuhan unhayngwon-**ul/i** tongney ssilum tayhoy-eyse   ungwonha-n] kenmwulcwu-lul
 wealthy   banker-**ACC/NOM** town   *ssilum* competition-at rooted.for-ADN landlord-ACC
     swunkyeng-i   maywu silhehayss-ta
     policeman-NOM very   dislike-DECL

SR: 'The policeman disliked the landlord a lot who rooted for the wealthy banker at the town *ssilum* com-
petition.'

OR: 'The policeman disliked the landlord a lot who the wealthy banker rooted for at the town *ssilum*
competition.'

EXPERIMENT 2

1-a/b: Preceding SR/OR context between Person 1 and Person 2

Person 1

twu myeng-uy chongcang-i   kyengchal-uy cosa-lul   patko issupnita

two people-GEN chancellor-NOM police-GEN   investigation-ACC receive.is

'Two chancellors have been investigated.'

han myeng-un phencipcang-**ul/i** noymwul wuswu yemuy-lo   yeppakha-n hyemuyi-ko   talun

one person-TOP editor-**ACC/NOM** bribe   eceiving suspicion-with hreaten-ADN suspicion.is-and other

han myeng-un hyencipcang-**ul/i** kongkum namyong hyemuy-lo   hyeppakha-n

one person-TOP editor-**ACC/NOM** public.fund embezzling suspicion-with threaten-ADN

yemuyimni-ta

suspicion.is-DECL

SR: 'One was suspected for having threatened the editor for taking a bribe and the other was suspected for
having threatened the editor for embezzling public funds.'

OR: 'One was suspected that the editor had threatened him for taking a bribe and the other was suspected
that the editor had threatened him for embezzling public funds.'

Person 2

kyengchal cosa-ey   uyhamyen twu chongcang-cwung han meyng-i   enlonin-ul   mannassta-ko

police   investivation-to according.to two chancellor-among one person-NOM journalist-ACC met-COMP

hapni-ta.

is.said-DECL

'According to the police report, one of the chancellors had met a journalist.'

Question by Person 2

enu chongcang-i enlonin-ul   mannasssupni-kka?

which chancellor-NOM journalist-ACC met-Q?

'Which chancellor met the journalist?'

SR/OR experimental sentence: 1-a/b with context (answer by Person 1) & 1-c/d without context

[sinmwunsa-uy phencipcang-**ul/i** noymwul swuswu-lo   hyepphakha-n] chongcang-i   enlonin-ul

newspaper-GEN editor-**ACC/NOM** bribe   receiving-with threaten-ADN   chancellor-NOM journalist-ACC

mannassupni-ta

met-DECL

SR: 'The chancellor who threatened the editor for taking a bribe met a journalist.'

OR: 'The chancellor who the editor threatened on suspicion of taking a bribe met a journalist.'

2-a/b: Preceding SR/OR context between Person 1 and Person 2

Person 1

two myeng-uy yaksa-ka   manhun salamtul-uy ip-ey   olunaylikoisssupni-ta

two people-GEN pharmacist-NOM many   people-GEN mouth-to climb.is-DECL

'People have been talking about two pharmacists.'

han yaksa-nun   maul icang-**ul/i**   elum nakksi kwumeng-eyse kwuhaynayss-ko talun

one pharmacist-TOP town head-**ACC/NOM** ice fishing hole-from   saved-and   other

yaksa-nun   icang-ul kkangphay-eykeyse kwuhaynaysssupni-ta

pharmacist-TOP head-ACC gang-from   saved-DECL

SR: 'One pharmacist saved the head of the town committee from a fishing hole and the other saved him
from a gang.'

OR: 'The head of the town committee saved one pharmacist from a fishing hole and he saved the other
from a gang.'

Person 2

somwun-ey uyhamyen twu yaksa-cwung   han meyng-i   cippaywon-ul chacawassta-ko

rumor-to   according two pharmacist-among one person-NOM mailman-ACC came.to.see-COMP

hapni-ta.

is.said-DECL

'According to a rumor, one of the pharmacists came to meet a mailman.'

Question by Person 2
enu   yaksa-ka   cippaywon-ul chacawasssupni-kka?
which pharmacist-NOM mailman-ACC came.to.meet-Q?
   'Which pharmacist came to meet a mailman?'

SR/OR experimental sentence: 2-a/b with context (answer by Person 1) & 2-c/d without context
[maul icang-**ul/i**   elum nakksi kwumeng-eyse kwuhaynay-n] yaksa-ka   cippaywon-ul
 town head-ACC/NOM ice fishing hole-from   saved-ADN   pharmacist-NOM mailman-ACC
    chacawasssupni-ta
    came.to.see-DECL
   SR: 'The pharmacist who saved the head of the town committee from an ice fishing hole came to meet the
       mailman.'
   OR: 'The pharmacist who the head of the town committee saved from an ice fishing hole came to meet the
       mailman.'

3-a/b: Preceding SR/OR context between Person 1 and Person 2
Person 1
twu myeng-uy   paywu-ka kwankyetoyn phokhayng saken-i   pototoy-n   hwu yenyeykyeyey
two person-GEN actor-NOM related   assault   accident-NOM was.reported-ADN after entertainment
    tayhan salamtul-uy silmang-i   chisosko.issupni-ta
    about people-GEN disappointment-NOM soar.is-DECL
   'After the story about the two actors that were involved in assaults was reported, people became greatly
       disappointed at the entertainment industry.'

han paywu-nun tulama-uy kukcakka-**lul/ka** pangsongkwuk   inkun swulcip-eyse phonghaynghayess-ko
one actor-TOP   drama-GEN writer-ACC/NOM broadcasting.station near bar-at   assaulted-and
    talun paywu-nun kukcakka-**lul/ka** twuskolmok-eyse phokhaynghayesssupni-ta
    other actor-TOP   writer-ACC/NOM back.street-at   assaulted-DECL
   SR: 'One actor assaulted a writer of a soap opera at a bar near the broadcasting station and the other actor
       assaulted a writer of a soap opera in an alley.'
   OR: 'A writer of a soap opera assaulted one actor at a bar near the broadcasting station and he assaulted the
       other actor in an alley.'

Person 2
poto-ey uyhamyen twu paywu-cwung han meyng-i   sengwu-lul   hyeppakhayssta-ko hapni-ta.
report-to according two actor-among   one person-NOM voice.actor-ACC threaten-COMP   is.said-DECL
   'According to a report, one of the actors threatened a voice actor.'

Question by Person 2
enu   paywu-ka sengwu-lul   hyeppakhaysssupni-kka?
which actor-NOM voice.actor-ACC threatened-Q?
   'Which actor threatened the voice actor?'

SR/OR experimental sentence: 3-a/b with context (answer by Person 1) & 3-c/d without context
[tulama-uy kukcakka-**lul/ka** pangsongkwuk   inkun swulcip-eyse phonghaynghayss-n] pwywu-ka
 drama-GEN writer-ACC/NOM broadcasting.station near bar-at   assaulted-ADN   actor-NOM
    sengwu-lul   hyeppakhaysssupni-ta
    voice.actor-ACC threatened-DECL
   SR: 'The actor who assaulted the writer of a soap opera at a bar near the broadcasting station threatened a
       voice actor.'
   OR: 'The actor who the writer of a soap opera assaulted at a bar near the broadcasting station threatened a
       voice actor.'

4-a/b: Preceding SR/OR context between Person 1 and Person 2
Person 1
twu myeng-uy soselka-ka   yocum   sinmwun-ey cacwu pototoykoissupni-ta
two person-GEN novelist-NOM these.days newspaper-on often is.reported-DECL
   'These days two novelists are reported frequently in the newspapers.'

han soselka-nun pwutay-uy sapyeng-**ul/i**   pataska kayspel-eyse cwukilyehayss-ko talun soselka-nun
one novelist-TOP unit-GEN   private-**ACC/NOM** sea.shore mud.flat-at tried.kill-and   other novelist-TOP
    sapyeng-**ul/i**   pwutay inkun yasan-eyse cwukilyehayesssupni-ta
    private-**ACC/NOM** unit   near mountain-at tried.to.kill-DECL

SR: 'One novelist tried to kill a private at the mud flat near the military unit and the other tried to kill a private at a mountain near the military unit.'

OR: 'A private tried to kill one novelist at the mud flat near the military unit and he tried to kill the other at a mountain near the military unit.'

Person 2

cosa-ey   ttalumyen twu soselka-cwung han meyng-i   kyengchal-ul   poassta-ko hapni-ta.
investigation-to according two novelist-among one person-NOM policeman-ACC saw-COMP   is.said-DECL

'According to the investigation, one of the novelists saw a policeman.'

Question by Person 2

enu   soselka-ka   kyengchal-ul   poasssupni-kka?
which novelist-NOM policeman-ACC   saw-Q?

'Which novelist saw the policeman?'

SR/OR experimental sentence: 4-a/b with context (answer by Person 1) & 4-c/d without context

[pwutay-uy sapyeng-**ul/i**   pwutay inkun yasan-eyse cwukilyekoha-n] soselka-ka   kyengchal-ul
 unit-GEN   private-**ACC/NOM** unit   near mountain-at tried.to.kill-ADN novelist-NOM policeman-ACC

   poasssupni-ta
   saw-DECL

SR: 'The novelist who tried to kill a private at the mountain near the military unit saw the policeman.'

OR: 'The novelist who a private tried to kill at the mountain near the military unit saw the policeman.'

APPENDIX B: INFERENTIAL STATISTICS

S-/scrmbld	in-situ	HEAD NOUN		GAP		INTERACTION H × G	
O-head	O-head	$F1_{(2,82)}$ $F2_{(2,70)}$		$F1_{(1,41)}$ $F2_{(1,35)}$		$F1_{(2,82)}$ $F2_{(2,70)}$	
famous	famous						
	conductor-NOM						
	(W2)						
vocalist-ACC/NOM	**vocalist-ACC/NOM**						
(W2)	**(W3)**			33.69*** 15.56***			
AdvP	**AdvP**						
(W3–W5)	**(W4–6)**			14.42*** 9.41**		9.25*** 5.12**	
invited-ADN	**invited-ADN**						
(W6)	**(W7)**			40.15*** 29.30***		10.35*** 7.18***	
conductor-NOM/ACC	**senator-ACC**						
(W7)	**(W8)**			21.71*** 16.99***		14.01*** 11.70***	
senator-ACC/NOM							
(W8)							
publicly insulted	publicly insulted			7.98** 4.94*			

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

TABLE B1. Inferential statistics for the rereading times in experiment 1.

	CONTEXT		GAP		INTERACTION C × G	
	$F1_{(1,35)}$	$F2_{(1,31)}$	$F1_{(1,35)}$ $F2_{(1,31)}$		$F1_{(1,35)}$ $F2_{(1,31)}$	
W1	12.48***	16.20***				
W2	7.07*	4.41*				
W3	50.99***	62.20**				
W4	55.05***	93.41***				
W5	64.62***	69.19***				
W6	69.29***	116.65***				
W7	52.24***	85.41***				
W8	24.64***	45.31***				
W9						

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE B2. Inferential statistics for the gaze durations of experiment 2.

	CONTEXT		GAP		INTERACTION C × G	
	$F1$(1,35)	$F2$(1,31)	$F1$(1,35)	$F2$(1,31)	$F1$(1,35)	$F2$(1,31)
W6	26.90***	25.06***	19.80***	12.68***		
W7	6.35*	10.68**	26.56***	32.26***		
W8			18.03***	13.65***		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE B3. Inferential statistics for the regression-path durations in experiment 2.

	CONTEXT		GAP		INTERACTION C X G	
	$F1$(1,35)	$F2$(1,31)	$F1$(1,35)	$F2$(1,31)	$F1$(1,35)	$F2$(1,31)
W1	8.11**	11.96***				
W2	20.35***	45.67***	4.91*			
W3	7.04**	8.86**	6.15*	6.17*		
W4	16.51***	28.36***	35.42***	23.69***	6.32*	4.16*
W5	40.91***	79.09***	38.40***	44.61***		
W6	46.75***	109.86***	34.70***	35.79***		
W7	62.15***	128.18***	24.02***	38.34***		
W8	40.27***	129.42***	14.18***	18.00***		
W9	17.82***	39.89***				

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE B4. Inferential statistics for the rereading times in experiment 2.

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