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Disambiguation and Integration in Korean Relative Clause Processing

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Abstract Previous studies on Korean relative clauses (RC) show that, with respect to processing, object-extracted relative clauses (ORC) are more difficult to process at the head noun than subject-extracted relative clauses within temporarily ambiguous contexts. ORCs, however, are predicted by experience-based processing models to incur a greater processing cost during early processing stages at the RC verb, since it is a likely locus of disambiguation for RCs in Korean, and because ORCs are a less frequent structure. Consequently, the current study investigates whether processing difficulty for ORCs manifests itself at the RC verb using eye-tracking methods, a simple sentence structure and a sentential-decision task. The results revealed significantly increased go-past reading times for ORCs at the RC verb. We believe this is a result of a less frequent structure being more difficult to parse during disambiguation. Accordingly, experience-based models of processing can accurately predict difficulty for ORCs in Korean.

Keywords Korean · Relative clauses · Eye-tracking · Experience · Ambiguity

Introduction

Relative clauses (RC) are a prominently discussed topic in the field of experimental linguistics. Crosslinguistic research has shown that among the large majority of languages which allow both subject-extracted relative clauses (SRC) and object-extracted relative clauses (ORCs), ORCs are both less frequent in corpora and more difficult to process and comprehend. Korean is an example of a language with this footprint. This has been demonstrated by Kwon et al. (Kwon 2008; Kwon et al. 2010, 2013, 2006) using self-paced reading (SPR),

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eye-tracking and event related potentials (ERP). However, even within Korean, there have been numerous explanations to account for the difficulty of ORC processing. The aim of the current study is to, after replicating the previous findings (i.e., ORC difficulty), use an eye-tracking experiment to tease apart the factors that contribute to the ORC processing difficulty found in Korean.

Korean Relative Clauses

In Korean, the RC precedes the head noun it modifies (i.e., RCs are head-final or prenominal). According to the World Atlas of Language Structures (Dryer 2013), languages with prenominal RCs are the second most frequent RC-ordering type (17%) after languages where the RC follows the head noun (i.e., head-initial or post-nominal languages, such as English; 70%). Examples of Korean head-final relative clauses are given below:

SRC: Op_i [GAP_i *Uywon-ul* *Kongyekha-n*] *Gijaneun$_i$-i* *Jinju-lul* *Boass-ta*

Op [*gap* senator-ACC attack-ADN] reporter-NOM Jinju-ACC saw

English: The reporter$_i$ [who$_i$ GAP_i attacked the senator] saw Jinju.

ORC: Op_i [*Uywon-i* GAP_i *Kongyekha-n*] *Gijaneun$_i$-i* *Jinju-lul* *Boass-ta*

Op [senator-NOM *gap* attack-ADN] reporter-NOM Jinju-ACC saw

English: The reporter$_i$ [who$_i$ the senator attacked GAP_i] saw Jinju.

Korean is a canonically SOV ordered language. As seen above, Korean RCs also demonstrate a canonical SOV word order. Additionally the only surface difference between the RC structures is the case marker suffixed to the RC noun (e.g., senator-ACC & senator-NOM). In both types of RCs, the RC is only overtly marked as a general embedded clause by the adnominal marker affixed to the embedded RC verb (e.g., attack-ADN). These features potentially make the RCs temporarily ambiguous during processing, since they lack an overt RC marker at the left boundary of the clause. This is particularly true since Korean also allows both pro-dropping and scrambling. In other words, without any facilitating discourse that could signal an initial RC interpretation, the parser might misconstrue an RC as a matrix clause until disambiguating information arrives. The phenomenon of clause type ambiguity is also present in other prenominal languages and is addressed prominently in RC studies dealing with Japanese (Miyamoto and Nakamura 2003; Ueno and Garnsey 2008) and Mandarin (Hsiao and Gibson 2003).

Kwon et al. (Kwon 2008; Kwon et al. 2010, 2013, 2006) have revealed much about the processing of Korean, and chiefly attribute the processing difficulty associated with ORCs to experience-based (i.e., expectation-based) effects (Hale 2001, 2006; Levy 2008; MacDonald and Christiansen 2002; Mitchell et al. 1995) and structural-phrase integration (O'Grady 1997) at the head noun. While Kwon et al. (2010) illustrates that the locus of disambiguation for each clause may vary in temporarily ambiguous contexts and that the head noun will guarantee a correct RC interpretation, the adnominal marker can at the very least disambiguate RCs from matrix clauses since matrix verbs lack adnominal markers. A brief review of both processing accounts is given below, followed by a review of Kwon et al.'s findings.

Experience-Based Models

Experience-based models of processing (Hale 2001, 2006; Levy 2008; MacDonald and Christiansen 2002; Mitchell et al. 1995), regard processing to be guided by our prior experience with a given language. Accordingly, a more frequent structure in a language will be easier to parse than a less frequent structure (see Demberg and Keller 2008; Husain et al. 2014; Levy et al. 2013; Reali and Christiansen 2007). Since Korean ORCs occur less frequently in corpora than their SRC counterparts (Kwon 2008), experience-based models predict that there should be greater difficulty when reading a Korean sentence containing an ORC compared to a SRC. For temporarily ambiguous structures, such effects based on the frequency of RC structures should not begin until the structure has been disambiguated. At this point the expectation that the RC is a more frequent SRC would be met, or there would be a dashed expectation if it is instead the less frequent ORC (Hale 2001, 2006; Levy 2008).

Evidence supporting an experience-based account for RC processing has already been revealed for Mandarin Chinese. Mandarin is another language which has prenominal, temporarily ambiguous RC structures, and in which ORCs occur less frequently than SRCs. What is more, Mandarin, similar to Korean, has a relativizer marker adjacent to the head noun. In an ambiguous context, this relativizer would be the locus of disambiguation for clause type. Studies by Lin and Bever (2006) and Qiao et al. (2012) found an increased processing cost at the relativizer position for ORCs within ambiguous contexts supporting experience-based predictions. Furthermore, Jäger et al. (2015) demonstrated that if the initial ambiguity is removed by creating a clause boundary for an embedded clause, SRCs become easier to process compared to ORCs prior to the relativizer in Mandarin. However, such clear and concrete evidence for an experience-based account has yet to be observed in Korean or other prenominal languages.

Integration-Based Models

For filler-gap dependencies (Chomsky 1965, 1981; Clifton and Frazier 1989; Fodor 1989; Hawkins 1999), the head noun is required to be integrated with the gap to assume its grammatical role within the RC; however, the mechanism for integration is not yet fully understood, and there are several competing models within the literature (c.f., Gibson 2000; Lewis and Vasishth 2005; O'Grady 1997). A basic principle for integration is that as the distance increases between the filler and the gap, integration becomes more difficult. Distance, however, has been defined differently by different researchers. Specifically, distance has been defined as: (1) linear-distance (Gibson 1998, 2000) based on the number of intervening syntactic dependencies on a linear plane, (2) temporal distance (Lewis and Vasishth 2005) based on the amount of time between the filler and gap, and (3) structural-phrase distance (O'Grady 1997) based on the number of intervening structural-phrase nodes in syntactic structure. For a language such as Korean, linear- and temporal-distance both would predict that integration for ORCs should be easier than SRC integration. This is because there are less discourse referents between the filler and gap. Meanwhile, the structural-phrase definition of distance predicts that ORCs should be more difficult than SRCs, as there are more intervening structural phrases between the gap and the object head than between the gap and the subject head. See Fig. 1 for an illustration of this.

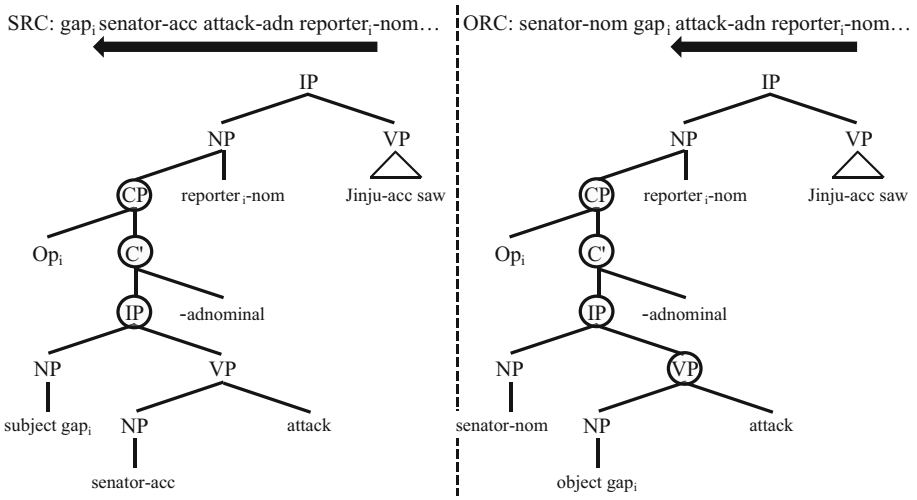

Fig. 1 Basic syntactic structure for Korean relative clauses. The *circles* represent the syntactic phrases intervening between the filler and gap for each RC. The *black arrows* represent the general linear/temporal distance between the filler and gap for each RC

Previous Findings in Korean

While Kwon and colleagues have effectively shown that ORCs are more difficult to process than SRCs in Korean, a general issue with these studies is that there are far too many accounts for this difficulty. In Kwon et al. (2010), experience, integration, similarity-based interference (Gordon et al. 2001) and successive NP marking (Lee et al. 2007; Nakayama et al. 2005) were all shown to contribute to ORC difficulty in eye-tracking studies. In temporarily ambiguous structures, Kwon et al. (2010) claimed that this processing difficulty starts with the introduction of the head noun. These findings, combined with Kwon et al. (2006) and Kwon et al. (2013), which both revealed no reliable observation of ORC difficulty prior to the head noun, would suggest that ORC difficulty in Korean begins at the head noun. As such, Kwon and colleagues claim that the locus of disambiguation for Korean RCs is the head noun. However, the following paragraphs describe how this point is debatable, given that adnominal markers likely correspond with an RC interpretation. This is supported by corpora findings and experience-based models, both of which explain the ORC difficulty found at the adnominal marker and how difficulty at the head noun most likely represent effects of integration as defined by a structural-phrase metric.

As mentioned previously, the adnominal marker in Korean at the very least allows the parser to eliminate an incorrect matrix clause interpretation for the RC structure. Kwon and colleagues hold the belief that the parser will wait until reading the head noun to construct a new interpretation for the RC, as the adnominal marker does not guarantee a RC reading. This is because other embedded clauses can also be marked with the same adnominal marker, and the surface structure of these clauses can appear nearly identical to an RC's until the adnominal marker. For instance, a *fact*-clause (see Kwon 2008, pp. 17–18) would appear identical to an RC except that instead of a subject or object gap, there would be a null pronominal in the underlying structure. The two clauses would differentiate at the head noun which would either be a RC noun (e.g., *gijaneun* 'reporter') or a de facto expression (e.g., *sasil* 'fact'). Kwon (2008) reported that the average frequency of RC headed clauses (12,154 per million) is higher

than fact-clauses (10,732 per million) within the Sejong corpus (see Kang and Kim 2004). A log-likelihood test revealed this difference to be significant ($\chi^2(1) = 88.41,\ p < .001$). Despite the two clause types being indistinguishable in ambiguous contexts at the embedded verb (e.g., attack-ADN), under the experience-based framework and the assumption that parsing is incremental and predictive (Kamide 2008; Kamide et al. 2003; Kamide and Mitchell 1999) the parser would have a greater expectation of encountering the comparatively more frequent RC structure, compared to the less frequent fact-clause. This expectation would be either met or refuted when the parser encounters the head noun (Hale 2001, 2006; Levy 2008). Nevertheless, RCs would still be more difficult to parse at the head noun, compared to a fact-clause. This is because RCs would have to undergo the integration of the filler and gap, whereas the fact-clause would not.

According to experience-based models of processing, if the parser is interpreting each clause as an RC at the embedded RC verb, then the ORC condition will begin to experience greater processing difficulty since it is the less frequent structure compared to SRCs. In fact, Kwon et al. (2010) was able to show marginal processing difficulty at the RC verb using temporarily ambiguous contexts and a significant difference with unambiguous RCs, both via regressive *go-past* measures (regression-path duration). Kwon et al. characterize this go-past measure as a later stage of processing and believe that it represents general comprehension difficulty. Accordingly, they did not attribute the difficulty found at the RC verb during go-past exclusively to experience-based resources. However, go-past has the potential of being interpreted as an early stage effect (c.f., Clifton et al. 2007) and it has been shown to be a valuable measure within other RC studies (Gordon et al. 2006; Staub 2010; Traxler et al. 2002). Considering that the head noun is not yet integrated into the sentence when the RC verb and the adnominal marker are read, there is nothing that could occupy the RC gap until the head noun is encountered. As such, the increased distance of filler-gap dependencies seems to be poorly suited to describe ORC difficulty at the RC verb before the reading of the head noun within ambiguous contexts. Accordingly, we interpret their results at the RC verb in both ambiguous and unambiguous contexts to be representative of experience-based effects which first appear due to the adnominal marker allowing for the disambiguation of clause type.

While we hold the view that the adnominal marker would serve as a clause type disambiguation point and therefore would incur a surprisal cost for ORCs during disambiguation (Hale 2001; Levy 2008), we also maintain that ORC difficulty at the head noun is better explained by structural-phrase integration. Specifically since RC clause type would likely be established at the adnominal marker, the head noun should not be a locus of high surprisal for either RC type.

In summary, we assert that the processing of Korean RCs within a temporarily ambiguous context should be reinvestigated to validate an experience-based resource account of ORC processing difficulty prior to the reading of the head noun.

Current Study

The present study will further investigate Korean RCs using eye-tracking. The main focus of this study is to confirm that the processing difficulty for temporarily ambiguous Korean ORCs begins at the embedded RC verb, as predicted by experience-based accounts of processing. A lesser aim of this study is to replicate the previous findings of Kwon and colleagues: we expect to find ORC difficulty at the head noun as predicted by the structural-phrase integration metric. In other words, we aim to show that both experience-based models and the structural-phrase integration model are accurate for Korean RC processing, and also that

these effects appear at different loci. Accordingly, we presented participants with Korean sentences containing either an initially ambiguous SRC or ORC and used eye-tracking to monitor reading. Unlike previous studies, we included a sentential-decision task about the overall plausibility of the target sentence (i.e., whether the sentence can be acceptable/said in the language without resorting to paranormal interpretations). We chose this approach over the typical post-sentence comprehension probe because there has been some indication that comprehension probes may be more task-demanding than is required to parse and comprehend the sentence (Caplan et al. 2008).

Experiment: Sentential Judgment Task Using Eye-Tracking

The aim of the current study was to investigate whether Korean ORCs are more difficult to process at the embedded RC verb than SRCs before the head noun is read. If this is so, this study can be understood as an indication of support for experience-based models of processing. A sentential judgment task and eye-tracking methods were used to capture eye-movements and reading times to reveal which RC type was more difficult to process.

Methods

Participants

Thirty-two native speakers of Korean were recruited from Nagoya University in Japan. Due to calibration errors, one participant was removed from the study ($N = 31$). All participants were either undergraduate or graduate students at the time of the study. Participants gave informed consent and received monetary compensation.

Materials and Apparatus

Thirty-two experimental items containing RCs were created for this study. All RCs modified the matrix subject of the sentence. Items were counterbalanced to ensure that a participant would only view either the SRC or ORC variant for a given target. A SRC and its ORC counterpart only differed in the case marking suffix at the end of the RC noun (SRC is N-ACC & ORC is N-NOM). The head noun was always marked with nominative case.

All experimental items were designed to have a relatively simple structure. The RC only contained the RC noun and verb, and the matrix clause consisted of the head noun, an adverb and an intransitive verb. In Kwon et al.'s (2010) items, there was an additional argument in both the RC and matrix clause. We used a simpler structure than their previous experiments because we wished to eliminate any processing difficulty related to parsing additional arguments.

All nouns were proper first names (e.g., Jinju and Minji). See below for an example of an item used in the study. The example below transliterates the target sentence into the Roman alphabet. However, Korean speaking participants were shown sentences written in Hangul. Since the secondary task was a sentential-correctness decision and all experimental items were semantically correct (e.g., plausible) utterances in Korean, 32 additional RC items (SRC = 16) were created that contained a semantically incorrect (implausible) verb at either the RC verb or matrix verb.

RC Noun	RC Verb	Head Noun	Adverb	Matrix Verb
[jinju-lul/ka	seoldeugha-n]	minji-ka	gyeolgug	nawassda
Jinju-ACC/NOM	persuaded-ADN	Minji-NOM	eventually	came.out

'Minji who persuaded Jinju (Jinju persuaded) eventually left.'

Stimulus sentences were displayed horizontally on the centre left of a 17-inch Mitsubishi LCD monitor at a distance of 70 cm from the head and chin rest mount. All characters were displayed in Korean (Gulim 25pt; visual angle of 2.05°). Eye movements were recorded using an EyeLink 1000 Core System (desktop EyeLink 1000 SR Research Ltd., Ontario, Canada). The resolution of the eye-tracker was 0.01° RMS, and the sampling rate was 1000 Hz (i.e., measured every 1 ms). Only right eye-fixation data was collected. An attached gamepad was used for button-response events.

Procedure

Participants were instructed to read Korean sentences displayed one at a time on a computer monitor, and told that they would be asked to judge whether the sentence was semantically correct (that is, able to be said or make sense in a real world setting without resorting to a paranormal interpretation) by pressing either the "True" or "False" marked buttons on the gamepad. They were asked to read and judge the sentence as quickly and accurately as possible while still maintaining accuracy and were given a maximum of eight seconds to complete each item in the task. Eight practice items were given prior to the experiment proper to ensure that the participants understood the task.

Prior to each experimental session, the camera was calibrated for each participant. This was accomplished by a 9-point calibration method and subsequent validation. Calibration was periodically repeated throughout each experimental session after block sessions (blocks of eight items) or when a participant was unable to accurately fixate on the mask (within a block session). Prior to each trial, a drift-correction fixation mask was presented at the centre left of the screen, the point at which the sentence would begin. Once the participant accurately fixated on the mask, the proctor would remove the mask and display the trial sentence. The participants then read each sentence and made their judgment using the gamepad (within eight seconds). After the button response, the stimulus item was immediately removed and no feedback was given. Reading times were measured from the onset of the stimuli to the button press response.

Eye-Tracking Measures

Reading time measures for the various processing stages (i.e., early and late) were collected for each word of the sentence. For eye-tracking measures, we follow Clifton et al.'s (2007) descriptions of eye-tracking. The earliest processing stage reported is *first-fixation duration* which refers to the first fixation made in an interest region consisting of only a singular fixation point. Next is *first-pass* reading time (RT) which is composed of all fixations made within an interest region from when the region is first entered (from the left) until the region is exited in either direction (left or right). This measure can be a collection of one or more fixation points; thus, it is equal to or greater than first-fixation duration. A key regression measure reported in this study is *go-past* RT, the total reading of an interest region (e.g., RC Verb) before the region is exited to the right (e.g., Head Noun) for the first time. This also includes any regressive readings out of the region to the left (e.g., RC Noun) before going

right. Therefore, go-past RTs are greater than or equal to first-pass RTs. The late processing measure reported in this study is *re-reading* time, the sum of all fixations after first-pass RT for an interest region (total time in the region minus first-pass RT). Additionally, *regression–out* (i.e., first-pass regression-out) *proportion* is reported where applicable. The total reading time of the sentence and accuracy ratings are also reported.

Results

Prior to the analyses, five trials were removed due to participants failing to make a judgment within the eight second trial period. For the remaining trials, all fixations below 80 ms were merged into a neighbouring fixation within a one-character distance (72 fixations). This was then followed by the removal of all remaining fixations under 80 ms and also fixations that exceeded 1000 ms resulting in the removal of 824 fixation points (7.17% of all fixations).

The collected reading times and binomial data (i.e., accuracy and regression-out) were analysed using linear mixed effect modelling (Baayen et al. 2008) and the *lme4* package (Bates et al. 2014) within R (R Core Team 2014). For every analysis, the fixed effect was RC type (ORC $= -.5$ & SRC $= +.5$) and the random effects were subjects and items (random intercept and slopes). Besides accuracy, all other analyses were done only on trials with correct judgments. Reading times were transformed using their natural logarithm and analysed with the *lmer* function with maximum likelihoods. Satterthwaite's approximations were used via the*lmerTest* package to generate p values for each model (Kuznetsova et al. 2014). For binomial data, the *glmer* function (binomial link function) was used to calculate the z distribution using maximum likelihoods and Laplace approximations (Harding and Hausman 2007; Jaeger 2008). Data outliers (RT data only) were trimmed based upon ± 2.5 standard deviations of the predicted model which resulted in the elimination of 1.58% of the data. In the sections below, the results of each region of the sentence is reported separately. Refer to Table 1 for means and standard errors (natural log transformation for RTs) and Table 2 for the detailed results of the linear mixed effect modelling.

Sentence

The overall processing of sentences did not differ between conditions. While the total reading time of all sentences revealed that the ORC condition was read more slowly than the SRC condition, this effect was only marginal ($p = .077$). In addition, the difference in judgment accuracy between ORC (83%) and SRC (87%) types was not significant ($p = .281$). Consequently, the overall processing data of the sentences alone could not reveal which condition was more difficult to parse.

RC Noun (Jinju-ACC/NOM)

At the reading of the first region of the sentence, there were no significant differences between conditions during first-fixation duration ($p = .247$) or first-pass RT ($p = .388$). As such, no difficulty was found for either condition during early measures of processing at the RC noun. Re-reading time, however, revealed a marginal difference ($p = .082$) between conditions, indicating that ORCs were read more slowly than SRCs during this later processing stage.

Table 1 Means for reading times, accuracies, and regression proportions

	ORC		SRC		p value
	Means	SE	Means	SE	
Sentence					
Total time	7.71	0.02	7.66	0.02	$p = .077$
Accuracy	0.83	0.02	0.87	0.02	$p = .281$
RC noun					
First-fixation	5.28	0.01	5.31	0.01	$p = .247$
First-pass	5.74	0.02	5.77	0.02	$p = .388$
Re-reading	5.88	0.04	5.77	0.04	$p = .082$
RC verb					
First-fixation	5.38	0.02	5.35	0.02	$p = .152$
First-pass	5.56	0.02	5.51	0.02	$p = .070$
Re-reading	5.97	0.04	5.91	0.04	$p = .226$
Go-pass	5.76	0.03	5.66	0.03	$p < .01$
Regression-out	0.18	0.02	0.13	0.02	$p = .378$
Head noun					
First-fixation	5.40	0.02	5.36	0.02	$p = .153$
First-pass	5.59	0.02	5.59	0.02	$p = .387$
Re-reading	5.90	0.04	5.90	0.04	$p = .846$
Go-pass	5.78	0.03	5.68	0.03	$p < .05$
Regression-out	0.18	0.02	0.12	0.02	$p = .169$
Adverb					
First-fixation	5.43	0.02	5.44	0.02	$p = .492$
First-pass	5.54	0.02	5.52	0.02	$p = .658$
Re-reading	5.63	0.04	0.54	0.04	$p = .797$
Go-pass	6.23	0.04	6.08	0.04	$p < .05$
Regression-out	0.47	0.03	0.40	0.02	$p < .05$
Matrix verb					
First-fixation	5.29	0.03	5.32	0.03	$p = .782$
First-pass	5.42	0.04	5.45	0.03	$p = .849$
Re-reading	5.70	0.08	5.78	0.07	$p = .265$
Regression-out	0.75	0.03	0.77	0.03	$p = .901$

Reading times in log transformations, accuracy and regression in frequency proportion

Embedded RC Verb (Persuaded-ADN)

For the RC verb, while first-past RT only displayed a marginal increase in RTs for the ORC condition ($p = .077$), go-past RT did reveal a significant difference between conditions ($p < .01$), demonstrating that participants spend more time reading ORCs before moving onto the head noun. However, despite the significant difference in go-past RT, the regression-out proportion was not significantly different between conditions ($p = .378$). Additionally, neither first-fixation duration ($p = .152$) nor re-reading time ($p = .266$) revealed any significant differences in RTs between conditions. This suggests that ORC difficulty begins during the early stages of processing, but that this difficulty does not persist on to later stages. This difficulty likely subsides after the adnominal marker (e.g., attack-ADN) was read, since first-fixation was not significant.

Table 2 Linear mixed effect modelling estimates and t/z values

	Estimate	SE	DF	t/z value
Sentence				
Total time	−.04708	.02526	20.58	−1.86†
Accuracy	.6559	.6084	979.00	1.08
RC noun				
First-fixation	.02548	.02	53.25	1.17
First-pass	.02308	.03	28.26	0.88
Re-reading	−.10003	.06	29.78	−1.803†
RC verb				
First-fixation	−.03513	.02	30.32	−1.47
First-pass	−.05225	.03	160.34	−1.822†
Re-reading	−.07711	.06	29.92	−1.24
Go-pass	−.09438	.04	193.51	−2.696**
Regression-out	−.2064	.23	823.00	−0.88
Head noun				
First-fixation	−.03352	.02	20.46	−1.48
First-pass	−.02489	.03	29.61	−0.88
Re-reading	.01188	.06	32.01	0.20
Go-pass	−.10758	.04	45.47	−2.475*
Regression-out	−.4583	.33	820.00	−1.38
Adverb				
First-fixation	.02048	.03	31.15	0.70
First-pass	−.01521	.03	28.01	−0.45
Re-reading	−.0157	.06	36.71	−0.26
Go-pass	−.15575	.06	66.00	−2.532*
Regression-out	−.4716	.20	768.00	−2.393*
Matrix verb				
First-fixation	.01	.05	22.12	0.28
First-pass	.01	.0	26.41	0.19
Re-reading	.12	.10	17.05	1.15
Regression-out	.04	.33	534.00	0.12

For reading time measures, a negative estimate indicates an increase in reading time in log transformed milliseconds for the ORC condition. For accuracy and regression measures, a positive estimate indicates an increase of accuracy or probability of regression. † $< .1$ * $p < .05$; ** $p < .01$; *** $p < .001$

Head Noun (Minji-NOM)

At the head noun, only go-past RT revealed a significant difference between conditions ($p < .05$). It was found that ORCs required more regressive readings back into the RC structure before moving into the adverb, compared with SRCs. First-fixation duration ($p = .153$), first-pass RT ($p = .387$), re-reading RT ($p = .846$) and regression-out proportion ($p = .169$) were not found to be significantly different between conditions.

Adverb (Eventually)

At the adverb, ORCs were read significantly more slowly than SRCs during go-past RT ($p < .05$) and were significantly more likely to regress-out back to a prior region ($p < .05$).

First-fixation duration ($p = .492$), first-pass reading ($p = .658$) and re-reading ($p = .797$), however, did not reveal any differences between conditions.

Matrix Verb (Came.out)

There were no significant differences between conditions during any reading time measure at the matrix verb (first-fixation duration ($p = .782$), first-pass reading ($p = .849$) and re-reading ($p = .265$) and regression-out proportion ($p = .901$).

General Discussion

The purpose of this study was to replicate the previous findings which showed that Korean ORCs are more difficult to process, compared to SRCs, and to provide a more detailed account of how and why this processing difficulty occurs. More specifically, the chief aim of this study was to demonstrate that ORC processing difficulty first arises after the disambiguation of the temporarily ambiguous RC, as explained by experience-based models.

The overall results of this study clearly demonstrated that the ORC condition was more difficult to process (i.e., required longer reading times) compared to its SRC counterpart. This was clear at multiple positions, including the RC noun, embedded RC verb, the head noun and the adverb region. This data strongly supports the general aim of the study. Similar to Kwon et al. (2010), there are several explanations for the higher processing cost of ORCs: experience-based effects (Hale 2001, 2006; Levy 2008; MacDonald and Christiansen 2002; Mitchell et al. 1995), memory-based effects of structural-phrase integration (O'Grady 1997) and similarity-based interference (Gordon et al. 2001). However, unlike Kwon et al. (2010), we are able to attribute these processing effects to different regions within the sentence.

Structural-Phrase Integration

At the parsing of the head noun, integration of the co-indexed filler and gap dependencies occurs. However, as mentioned before, if this backwards anaphoric search for the gap utilizes a linear-based (Gibson 1998, 2000) or a temporal-based (Lewis and Vasishth 2005) mechanism, then ORCs should actually be easier to process at the head noun since there is less intervening discourse separating the filler and gap at the surface structure. However, according to the structural-phrase integration model (O'Grady 1997), ORCs are more difficult to process since there are more syntactic-phrases intervening between the filler and gap in ORCs than in SRCs (refer to Fig. 1). Nearly identical to Kwon et al. (2010), go-past RTs in the current study provide evidence for a structural-phrase integration model and cannot currently support either the linear- or temporal-based models. Considering that Kwon et al. (2013) revealed that the difficulty at the head noun is similar to integration effects in English (Gouvea et al. 2010) and Japanese (Ueno and Garnsey 2008), it is likely that integration-based effects are at least partially inducing longer reading times for ORCs at the head noun. However, integration-effects cannot account for the processing difficulty during go-past RT at the RC verb since it is not the locus of integration in Korean RCs.

In the discussion below, we will eventually argue for an experience-based account at the embedded RC verb. However, it is not likely that experience-based effects are driving the difficulty at the head. For instance, as revealed by Kwon (2008), RCs as a whole are more difficult to process at the head than fact-clauses due to integration, despite the fact that RCs are

a more frequent structure than fact-clauses. In the current study, if experience-based effects were originating from the RC verb, we would expect these effects at the head noun to be seen immediately. However, difficulty at the head noun did not begin until go-past reading. While we argue that go-past should be considered an early measure of processing, go-past at the head noun should be viewed differently than the significant difference during go-past at the RC verb. This is because first-fixation and first-pass reading at the head noun failed to show longer reading times for the ORC condition. Consequently, experience-based effects and integration-based effects appear to be disassociated from each other at different loci within the sentence. Because of this, we believe that both models are valid for Korean RC processing. While the locus of integration appears at the head noun, the locus of experience-based effects in Korean is found at the embedded-RC verb prior to its head.

Similarity-Based Interference

Under the framework of similarity-based effects (Gordon et al. 2001, 2006; Lee et al. 2007), storing multiple nouns with similar features into working memory creates a difficulty during the retrieval of a noun. Since the RC noun in this study shared many of the same features as the head noun for ORCs (i.e., case-marking, animacy and proper name), under this theory, these two nouns compete with each other in working memory. This competition could increase the processing cost. This can be supported by the increased go-past RTs at the head noun and adverb. As Kwon et al. (2010) notes, having two successive nouns marked with nominative case could also have increased RTs for ORCs at the head noun and prior regions during later stages of processing. This would partially explain the longer re-reading RTs at the RC noun. However, similar to integration-resources, similarity-based interference cannot explain the difficulty for ORCs before the head noun was parsed (i.e., the go-past RT at the embedded RC verb).

Experience-Based Effects

According to experience-based models of processing, less frequently occurring structures in a language will be more difficult to process than more frequently occurring structures (Hale 2001, 2006; Levy 2008; MacDonald and Christiansen 2002; Mitchell et al. 1995). However, as mentioned before, in temporarily ambiguous structures, RC frequency effects will not be observable until the structure is disambiguated. Accordingly, a lack of significant effects during the early stages of processing at the RC noun and during first-fixation duration at the RC verb (since multiple fixations are likely needed to read the verb and its morphology) are not in conflict with experience-based models. This is because, at these early stages of processing, the structure would likely still be ambiguous. All the effects found in this study are potentially compatible with frequency-based effects. However, as previously mentioned, the effects at the head noun and adverb regions are better explained by structural-phrase integration-effects and similarity-based interference effects.

In order to observe experience-based effects of processing alone (i.e., without other contributing factors such as integration or similarity-based interference), it is necessary for reading times in the ORC condition to be longer, prior to the reading of the head noun. Since this study used temporarily ambiguous RC structures, processing difficulty due to experience-based effects of RC structure type should not occur until the parser has disambiguated the

(correct) RC structure from a (more frequently seen, but incorrect) matrix clause interpretation. While there may be different loci of disambiguation for each clause type, it was likely that readers could correctly predict the RC structure at the full reading of the embedded RC verb (i.e., verb-adnominal) for both the RC types. Thus, because ORCs are less frequent in Korean, they were more difficult to parse after disambiguation. This was indicated by the significant difference during go-past RT and the marginal difference in first-pass RT at the RC verb. In addition, the difficulty found at the head noun, adverb and re-reading at the RC noun indicate greater processing difficulty for the less frequent ORC structure. Accordingly, these results provide general support for experience-based models of processing. In the subsections below, we discuss disambiguation and evidence for experience-based models.

The Locus of Disambiguation and Evidence for an Experience-Based Account

As mentioned above, RCs in Korean have the potential to be initially ambiguous, meaning that the parser would be unaware that the structure was a RC until a locus of disambiguation. For ambiguous contexts, the first possible locus would be the adnominal marker suffixed to the embedded verb (e.g., attack-ADN). While this locus would eliminate the matrix clause interpretation, the embedded clause would still be ambiguous, as there are other possible embedded clauses in Korean, such as fact-clauses (e.g., subject-pro senator-ACC attack-ADN). As such, Kwon and colleagues claim that the parser needs to wait until the head noun, allowing it to distinguish a fact-clause (e.g., *sasil* 'fact') from a RC (e.g., *gijaneun* 'reporter'). Admittedly, it is possible that since the two structures are too similar, the subject/object asymmetry at the embedded verb can be explained by the general frequency of Korean embedded clauses (which lack either an overt subject or object). This would, nevertheless, still support an experience-based account for the ORC difficulty at the embedded verb (e.g., attack-ADN). In other words, regardless of the initial interpretation made at the adnominal marker, the processing difficulty for ORCs at this locus would still appear. However, we hold the view that the structure would likely be interpreted as an RC. As previously mentioned, Kwon had reported that the head of an embedded clause affixed with the adnominal marker was more frequently an RC. Taking a more fine-grained approach, the parser would prefer an RC interpretation here. Future studies focusing on the differences in processing between fact-clauses and RCs prior to the head in Korean may be needed to clarify this.

Taking a look at *because*-clause structures in Korean (which are marked with—*se* 'because'), at the reading of the because-marker (e.g., attack-because), there is no longer an ambiguity of clause type at the marker. In fact, Kwon (2008) was able to show a significant difference between subject/object null pronominals. This can be attributed to the extreme rarity of Korean null objects. Accordingly, experience-based models (Hale 2001, 2006; Levy 2008) seem to be an accurate predictor of processing difficulty for embedded clause structures at the locus of the embedded verb and suffixed marker in the Korean language. However, it stands to the question if there are any other possibilities that might explain the difficulty for ORCs prior to the head noun.

At the first reading of the RC noun, both the accusative and nominative marker can elicit difficulty for SRCs and ORCs respectively. As Kwon et al. (Kwon 2008; Kwon et al. 2010, 2013, 2006) discuss, while a sentential initial, accusative-marked NP may be more difficult to process (since it would indicate either scrambling or a null subject), a nominative-marked NP could also be difficult, since there is less predictability for a transitive verb than an accusative NP. For the ORC condition, there could be some difficulty at a transitive verb (prior to the reading of the adnominal marker) since the parser would have to posit a null object pronominal. In summary, early SRC difficulty would be seen at the RC noun, and

ORC difficulty would be seen at either or both the RC noun and verb. However, Kwon et al. (Kwon 2008; Kwon et al. 2010, 2013, 2006) and the current study did not observe any initial difficulty for accusative- or nominative- marked NPs in the embedded clause, either by self-paced reading, eye-tracking or ERP methods. As such, verb transitivity and a single nominative marked NP may not be that difficult for the parser to handle. Though this has already been argued by Kwon et al. (2013, p. 29), more studies on either Korean or Mandarin are likely needed to clarify the strength, reliability and time-course duration that the effects of case marking would have during sentence processing.

The current study reports slightly, but still critically, different results from previous studies on Korean RCs. Because of this the following section will explain possible sources for these differences.

Comparison to Previous Studies

In Kwon et al. (2006) and Kwon et al. (2013), there was no processing difficulty associated with the embedded RC verb when using both SPR and ERP. Furthermore, Kwon et al. (2010) only revealed marginal effects for temporarily ambiguous structures at this position using eye-tracking. From these results, Kwon and colleagues claim that disambiguation in Korean does not occur until the head noun, a position where each study revealed significant findings. There are four explanations as to why our findings may conflict with the previous studies: differences in (1) experimental technique, (2) task methodology, (3) materials and (4) the analysis and interpretation of the results.

In the previous SPR and ERP studies, participants were only allowed to view a sentence one word at a time. In other words, participants were incapable of re-reading previous regions. For eye-tracking in general, go-past measurements have often been an important measure of processing difficulty in RCs (Gordon et al. 2006; Kwon et al. 2010; Staub 2010; Traxler et al. 2002). Considering that Korean RCs are both prenominal and ambiguous, go-past may be considered as an early processing stage for Korean RCs. At the very least, go-past should be considered a highly indicative measure of RC processing difficulty, as both the current study and Kwon et al. (2010) largely reveal ORC difficulty via go-past measures. Since SPR and ERP techniques lack such a measure, it could be that it is more difficult to view a processing cost at the RC verb within a moving-window paradigm.

Another difference between experiments was the secondary task method. The current study admittedly used a method not frequently used in eye-tracking studies. However, we do not believe the use of a sentential judgment task has skewed our results in a way that would make them misrepresentative. This is because the current study replicated the general findings of Kwon and colleagues. As previously mentioned, the motivation for using this task in place of comprehension probes was that comprehension probes may be a more demanding task, as they require participants to store target items in memory for the purpose of answering a question (Caplan et al. 2008); however, more studies are needed to show the detailed relationship between task methodology and sentence processing.

Additionally, the current study used materials of a simpler structure than Kwon et al. (2010). The motivation for using simpler structures was that Kwon et al.'s items may have been unnecessarily difficult for participants to process, given that they contained more information than was required to show the differences between RC types. Thus, we decided to remove extra arguments in both the RC and matrix clause. Since a simpler structure may be easier to process than a more complex structure, simpler items may account for some of the differences between studies.

Lastly, the current study and Kwon et al. (2010) may not differ entirely. In Kwon et al. (2010), difficulty for ORCs was seen at the RC verb for ambiguous contexts, albeit marginally, during go-past measures. Considering that Kwon et al. (2010) used classical ANOVA measures, it remains unseen whether or not their results would have reached significance if they had adopted to use LME. Consequently, a main difference between the current study and their results could simply boil down to the statistical methods used. While Kwon et al. (2010) do not fully commit to an experience-based account at the RC verb, we assert that this account best explains the ORC difficulty encountered during both studies. Also, it is possible that our results are also compatible with Kwon et al.'s second experiment, which also featured unambiguous RCs. A discussion on this will be given in the subsequent section.

The Issue with Ambiguity and Discourse Priming

While the current study only investigated RCs with a temporarily ambiguous structure, Kwon et al. (2010) conducted a second eye-tracking experiment using facilitating contexts (i.e., discourse priming) that would disambiguate the RC. However, no processing difficulty based on RC type was observed before the embedded RC verb in their study. This is peculiar, as ORCs should be initially more difficult to process at the RC noun if the parser correctly took an initial RC interpretation. Here, the case marker would disambiguate for RC type. This means that ORCs should have a higher processing cost due to greater surprisal for the structure (Hale 2001; Levy 2008). While it was shown that including a facilitating context did indeed speed up the reading of the clause, no difference between RC types was shown prior to the RC Verb. Considering that the results of the current study and both of Kwon et al.'s (2010) experiments are similar (i.e., marginally or significantly longer go-past times for ORCs at the RC verb), it is not clear whether participants took an initial RC interpretation in Kwon's study. In other words, the question remains whether discourse priming attenuated the expected difficulty for ORCs at the RC noun or whether the discourse did not prime for an RC interpretation. If the latter is accurate, then the results of the current study and Kwon et al. (2010) both can support the same claim that experienced-based effects are first predicted at the embedded RC verb for ORCs prior to the reading of the head noun under ambiguous contexts. The current study cannot support either possibility, but evidence from another prenominal RC language may shed light on this issue.

Recently, there has been some criticism against discourse priming methods for prenominal RCs. Gibson and Wu (2013), using this technique, found an ORC advantage for Mandarin Chinese RCs, which they claimed supported a linear-based integration mechanism and conflicted with experience-based models (i.e., SRC advantage). However, Lin (2014) and Vasishth et al. (2013) both provide evidence that Gibson and Wu's (2013) observation is better explained by thematic priming from the preceding discourse. As mentioned in the introduction, Jäger et al. (2015), using the target sentences from Gibson and Wu (2013), revealed that if the initial ambiguity is removed by creating a clause boundary for an embedded clause rather than using the priming technique, SRCs would initially become easier to process in Mandarin as explained by experience-based models. For Mandarin Chinese at the very least, removing the initial clause type ambiguity can influence whether experience-based models correctly predicted the data or not.

Since methodology may be a confound, we believe that more studies are needed, using both ambiguous and unambiguous structures, to reveal a better account of processing for Korean RCs prior to the head. Additionally, we feel that other methods in conjunction with discourse priming may be needed to attenuate the initial clause type ambiguity found in Korean RCs as well as RCs in other prenominal RC languages (e.g., Japanese and Mandarin Chinese).

Experience-Based Effects in Other Prenominal Languages

Overall, experience-based processing costs for a less frequent structure at the locus of disambiguation within a temporarily ambiguous RC structure are common for prenominal languages. As previously mentioned, several studies on Mandarin Chinese (Jäger et al. 2015; Lin and Bever 2006; Qiao et al. 2012) show ORC difficulty at the disambiguating relativizer morpheme or prior if the initial clause type ambiguity is attenuated. Both these effects are predicted by experience-based models. Therefore, the current results at the RC verb appear to be consistent with prior experience-based processing effects found in Mandarin Chinese while adding support to the account for Korean.

However, there is at least one prenominal language that shows an opposite trend. Carreiras et al. (2010) report that in Basque (i.e., Euskara), ORCs are easier to process at the disambiguation region for their items, which happened to be the ultimate or penultimate word in the sentence, despite ORCs being less frequent. At first glance, this would appear to be strong evidence against experience-based effects (Grodner and Gibson 2005; Pickering et al. 2000). However, unlike Korean, Mandarin Chinese and Japanese, RC type could not be distinguished easily in their study since a SRC or ORC interpretation was not possible until the matrix verb. Carreiras et al. (2010, p. 83) themselves bring up that the SRC difficulty may be likely due to a garden path effect for the SRC structure, which is caused by the ambiguity of the morphemes affixed to the RC noun, which assign number and indicate grammatical role. In other words, the morphemes on the RC noun for SRCs and ORCs appeared identical (e.g., *-ak* 'plural' for SRCs and *-a-k* 'singular+Subject' for ORCs). What is more, this confound appears not to have been addressed in later experiments in their study. Accordingly, it is difficult to understand their results as against experience-based models, at least until future studies resolve this confound. It is our prediction that if this issue could be resolved, then ORC difficulty would appear at the complementizer marker, which sits at the right boundary of the RC. If this proves to be accurate, Basque would appear consistent with Mandarin Chinese and Korean under the framework of experience-based models. For ambiguous RCs in Japanese, however, there is not a way to view experience-based effects prior to the head which is also the locus of integration. Consequently, it may be too difficult to tease apart experience-based and integration-based resources at the head noun.

In summary, experience-based effects may be limited to or best seen at a locus of ambiguity for RCs. However, they are nonetheless integral for the proper prediction of processing difficulty within ambiguous and unambiguous RCs. Considering that there is also evidence against frequency effects, we believe more studies are needed to investigate if there are underlying factors which could explain whether or not experience based models are more tightly connected to the processing of specific structure or contexts. Nevertheless, the current study adds empirical evidence within a prenominal RC language to the growing body of literature supporting experience-based models for relative clause processing.

Conclusion

In this study, we sought out to support the claim that ORCs in Korean are more demanding than SRCs with respect to processing. More specifically, we aimed to determine whether experience-based accounts of processing can accurately predict greater difficulty for ORCs before the reading of the head noun. Not only did the results support the main hypothesis, we also replicated previous findings at the head noun, supporting the claim that integration

in Korean likely uses a structural-phrase integration mechanism. In other words, the current study adds to the previous literature by showing that the effects of integration and experience are dissociated with each other and appear at separate loci within the sentence. Accordingly, the current study adds support from the Korean language for an experience-based account at the locus of disambiguation for RC processing similar to that of other prenominal languages such as Mandarin Chinese. In conclusion, temporarily ambiguous ORCs first incur processing difficulty at the locus of disambiguation as a result of being the less frequent structure prior to the integration of the filler and gap dependencies.

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Compliance with Ethical Standards

Conflict of interest None.

Human and Animal Rights Statement All personal information collected from participants was stored in a secured location, and participants were given pseudonyms for data analysis purposes. Participants were not subject to harm and could only experience mild discomfort from prolong seating or eye discomfort from prolong reading.

Informed Consent In the current study, all participants gave informed consent and received monetary compensation.

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