JSLHR

Research Article

Relative Clause Sentence Processing in Korean-Speaking School-Aged Children With and Without Specific Language Impairment

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Purpose: The goal of this study was to examine online and off-line sentence processing using Korean language relative clause sentences between children with specific language impairment (SLI) and children with typical development (TD).
Method: Twenty-four children with TD and 19 children with SLI participated in this study. Children completed online and off-line sentence-processing tasks using relative clause sentences. The response time (RT) data obtained from the online processing task were analyzed at each word position and between adjacent words for items answered both correctly and incorrectly on the off-line comprehension task. A linear mixed-effects model and a generalized linear mixed-effects model were used to analyze the performances on the online/off-line sentence-processing task between the two groups.
Results: The results revealed that the processing pattern of RTs on the online processing task differed between the two groups, such that the SLI group did not show the predicted RT increase while the TD group did. Also, the SLI group processed each word with comparable or faster reading rates than the TD group. On the off-line comprehension task, the SLI group performed poorly compared to the TD group.
Conclusions: Processing of syntactically complex sentences differed between the TD and SLI groups, such that the SLI group had lower accuracy on the off-line comprehension task and was less efficient on the online processing task as compared to the TD group. These results mainly support the syntactic deficit account in children with SLI.

Specific language impairment (SLI) is a developmental language disorder that manifests "specifically" in the language domain, independent of any obvious mental or physical disability, hearing loss, emotional problem, and so forth (Leonard, 1998). Although morphological limitations in children with SLI have been examined extensively (Friedmann & Novogrodsky, 2004; Leonard et al., 2003; van der Lely, 2005), acquisition of complex syntactic structure has rarely been examined (Hesketh, 2006). Sentences with relative clauses (RCs) are widely used in studying the acquisition of complex syntactic structure, not only in typically developing children (Arosio et al., 2011) but also in children with language impairment (Friedmann & Novogrodsky, 2004, 2007). It has been documented that children with SLI have poorer comprehension of complex sentences than do children with typical development (TD).

Accounts have been suggested for the basis of comprehension difficulty in children with SLI. These include the "syntactic deficit account" (van der Lely & Harris, 1990) and the "impaired processing account" (Hestvik et al., 2010; Leonard, 1998; Yim & Yang, 2018). However, the specific reason for limited sentence comprehension in children with SLI is still unclear.

The current study investigated whether children with SLI show difficulties in both real-time processing and off-line comprehension in processing RC sentences compared to children with TD. The rationale will be laid out as follows: Theoretical accounts of sentence processing in children with SLI will be followed by considerations of cross-linguistic differences in Korean RC sentences and their formations.

Sentence Processing in Children With SLI

The syntactic deficit account has been suggested as one of the accounts for explaining poor performance of sentence comprehension in children with SLI. This account

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Editor-in-Chief: Sean M. Redmond
Editor: Jan de Jong
Received April 10, 2018
Revision received August 22, 2018
Accepted October 22, 2020
https://doi.org/10.1044/2020_JSLHR-19-00373

Disclosure: The authors have declared that no competing interests existed at the time of publication.

highlights the lack of morphosyntactic knowledge as the main reason for failing to comprehend complex sentences correctly.

van der Lely and colleagues (Marinis & van der Lely, 2007; van der Lely, 1996, 2005; van der Lely & Harris, 1990) support a syntactic deficit account and proposed that the representational deficits of grammatical dependency between two positions in a sentence may cause syntactic difficulty in children with SLI. That is, children with SLI may not build a proper hierarchical grammatical structure by moving and assigning an appropriate thematic role to the noun phrases (NPs) in the movement-driven structure. Thus, the limited syntactic knowledge of children with SLI is explicit in nonlocal dependencies within a syntactically complex sentence, such as *wh*-questions, RCs, and passive voice.

For instance, van der Lely et al. (1998) demonstrated that grammatical deficits underlie atypical development in the language of children with SLI. van der Lely et al. presented a case study, focused on a 10-year-old boy with SLI. They administered a series of tests, distinguishing between grammatical abilities, nongrammatical language abilities, and nonverbal cognitive abilities. Examples of grammatical abilities they identified include using combinatorial rules, inflectional morphological rules for past tense, syntactic knowledge of assigning reference to pronouns, and reflexives. For nongrammatical language abilities, examples included pragmatic knowledge, logical inference, and verbal logical reasoning. As for nonverbal cognitive abilities, the researchers included processing complexity and response time (RT), auditory processing, and standardized nonverbal cognitive test results. Results showed that the participant's performances on grammatical language tasks had been significantly poorer than age-matched children or even younger children. However, children with SLI's performances in other categories were all in a normal range when compared with children with TD, supporting a discrete grammatical language deficit account.

Unlike researchers (e.g., van der Lely, 2005; van der Lely & Harris, 1990) claiming a syntactic deficit account for the cause of SLI in children, others have suggested that it may be due to slower processing mechanisms. In the impaired processing account, children with SLI have an intact grammatical system, although the development of syntax is slower than children with TD. These would manifest as delayed gap-filling in RC sentences compared to children with TD, a domain-general account (Hestvik et al., 2010; Leonard, 1998). Hestvik et al. (2010) used both online and off-line sentence-processing tasks to examine the cause of syntactic difficulty for RC sentences in children with SLI. They hypothesized that if children with SLI had impaired syntactic knowledge, their filler–gap activation after a relative verb would not be available for the online task, and their accuracy with the off-line comprehension task would be lower compared to children with TD. They also noted that, for the online task, a lack of filler–gap activation in children with SLI would not rule out that children with SLI have impaired processing mechanisms. Study results were that children with SLI showed different online processing performances than children with TD (there was no activation effect in gap-filling constructions on the online task), but no difference with the off-line comprehension task. These findings suggest that children with SLI may have intact syntactic knowledge, but they are slower in real-time processing. The evidence suggests that children with SLI tend to have an impaired processing mechanism rather than a deficit in grammatical knowledge. However, as Hestvik et al. mentioned in this study, van der Lely (2005) suggested interpretative caveats for using limited processing in distinguishing domain-general and domain-specific accounts. In other words, since processing and knowledge are related, the impaired processing of sentences observed in children with SLI does not necessarily mean that it is due to some lower level of processing.

Despite many studies investigating an advantage of subject relative clause (SRC) over object relative clause (ORC) in processing, using both online and off-line processing tasks in children with SLI, for languages with postnominals,[1] relatively few studies have examined RC sentence processing in children with SLI in languages with prenominal RC (Sasaki, 2016), especially in Korean. There are also very few studies investigating RC sentence processing using both online and off-line sentence-processing tasks, with a focus on the Korean adult population (Kwon et al., 2010).

In the current study, we used an online real-time measurement for RTs and an off-line RC sentence-processing task for comprehension measurement to investigate the pattern of processing difficulty in the Korean language, comparing children with SLI and children with TD. Using both the real-time processing task and the off-line comprehension task in sentence processing was not guaranteed to disentangle the two competing accounts of the underlying mechanism causing difficulty of RC sentence comprehension in children with SLI. However, if the off-line comprehension performance were good, combined with an atypical real-time pattern, then impaired processing might be a more influential account than syntactic deficit. On the other hand, if the off-line comprehension performance were poor, combined with an atypical real-time pattern, then the syntactic deficit account might be the better supported account.

Cross-Linguistic Differences for RC Sentences Between Korean and English

RC sentences represent a complex sentence type widely used in research on language acquisition due to the unique characteristics of asymmetry of SRC and ORC. This "asymmetry" refers to an advantage ascribed to SRC, in processing difficulty, over ORC. The difficulty of processing ORC sentences compared to that of processing SRC sentences is well documented in previous studies using various languages, including postnominal RC positions (Caplan et al., 2008) and prenominal RC positions (Kwon et al., 2013; Miyamoto & Nakamura, 2003).

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[1]In a language with postnominals, the head noun follows the RC like in English, whereas in a language with prenominals, the RC follows the head noun like in Korean. The head noun is the one RC modifies.

The type of RC sentence can be also divided into HSM and HOM, depending on whether the head noun that the RC modifies is a subject in the matrix sentence (HSM) or an object in the matrix sentence (HOM). Therefore, depending on the grammatical role of a head noun in the RC and in the matrix sentence, four different constructions are possible. In the example RC sentences below, (1-a) is an SRC sentence, with the head noun, "the dog," being the subject of both the matrix sentence (HSM) and the RC. Meanwhile, (1-b) is an ORC sentence, with the head noun being the subject of the HSM and the object of the RC. Likewise, (1-c) is an SRC sentence, with the head noun being the object in the HOM and the subject in the RC, whereas (1-d) is an ORC sentence, with the head noun being the object of both the HOM and the RC.

(1-a) KOR: *goyangi-reul mu-neun gae-ga ori-reul mukkeoyo*
cat-ACC bite-ADN dog-NOM duck-ACC tie up
ENG: The dog that bites the cat ties up the duck.
(HSM_SRC)

(1-b) KOR: *goyangi-ga mu-neun gae-ga ori-reul mukkeoyo*
cat-NOM bite-ADN dog-NOM duck-ACC tie up
ENG: The dog that the cat bites ties up the duck.
(HSM_ORC)

(1-c) KOR: *goyangi-ga ori-reul mukk-eun gae-reul mureoyo*
cat-NOM duck-ACC tie up-ADN dog-ACC bite
ENG: The cat bites the dog that ties up the duck.
(HOM_SRC)

(1-d) KOR: *goyangi-ga ori-ga mukk-eun gae-reul mureoyo*
cat-NOM duck-NOM tie up-ADN dog-ACC bite
ENG: The cat bites the dog that the duck ties up.
(HOM_ORC)

Research has attributed the asymmetry of SRC and ORC processing in comprehension to various accounts, including linear/temporal distance, phrase-structural complexity, experience-based, and similarity-based interference accounts. The linear/temporal distance account suggests that the greater the distance between the filler and the gap, the greater the cognitive resources (e.g., working memory) required until the filler–gap integration is completed. This is because memory decay is more likely to occur as the distance expands between the filler and the gap (Gibson, 2000). The phrase-structural complexity account suggests that the hierarchical phrase-structural distance (the number of XP categories) between the filler and the gap determines the difficulty of processing of RC sentences. That is, as the number of XP categories increases, the processing difficulty also increases (O'Grady, 1997). The experience-based account proposes that the frequency of exposure to a certain structure influences parsing decision (MacDonald & Christiansen, 2002). The similarity-based interference account suggests that the magnitude of difference between SRC and ORC is greater when two NPs are similar (i.e., both are same proper nouns or same descriptive nouns) compared to when two different NPs are used (i.e., one is a proper noun and the other is a descriptive noun) in the RC sentences (Gordon et al., 2001).

Given the cross-linguistic differences, the current study's scope is restricted to the processing pattern of SRC/ORC sentences in Korean, which has linguistic features differing from those of English. The primary difference between English and Korean is that English is an SVO (subject–verb–object) language, whereas Korean is an SOV (subject–object–verb) language. Although the canonical word order in Korean is subject–object–verb, it is relatively flexible compared to English given its usage of case markers. Korean uses case markers to indicate the grammatical roles in a sentence, whereas there are few case markers in English. Additionally, head nouns follow RCs in (postnominal) Korean, whereas RCs follow head nouns in (prenominal) English.

Case markers and the postnominal character of the Korean language mean that only case markers signify the difference between SRC and ORC sentences. The case marker, whether nominative (NOM) or accusative (ACC), is affixed to a noun in the formation of an RC.

Furthermore, contrary to English, where a relative pronoun is canonically located between head noun and RC, Korean affixes adnominal markers (*–eun/–neun*) to RC verbs placed before head nouns. These characteristics make RC sentences temporarily ambiguous. That is, a parser may interpret the contents of an RC as if they belonged to a main clause until they encounter the adnominal marker (ADN). For instance, when reading (1-a) or (1-b), the first NP can be interpreted as either object or subject of a main clause until the parser registers the adnominal-marked RC verb. Likewise, RC sentences like (1-c), which start with two NPs, are temporarily ambiguous because the parser can interpret the NPs as subject and object of a main clause following canonical word order. This will temporarily mask the RC until the parser encounters the RC verb with its adnominal marker (Kwon et al., 2010). Given the different linguistic features in the Korean RC sentences, the focus was given to the critical regions in a sentence when analyzing the data obtained from the online processing task.

Critical Regions of RC Sentences in Korean

For the processing of RC sentences in Korean, the head noun and RC verb (the verb in the RC) were selected as the critical regions in the current study (Kwon et al., 2010; Mansbridge et al., 2016). Kwon et al.'s (2010) adult study examined the asymmetry of SRCs and ORCs in Korean using an eye-tracking methodology. In their first experiment, Kwon et al. found longer regression path durations and rereading times, for RC verbs and head nouns, in ORC sentences compared with SRC sentences in an HSM construction. With the HOM construction, however, there were no RT differences for the head noun when comparing SRCs and ORCs. For the RC verb, the regression path duration was longer for ORCs than for SRCs, while the rereading time was similar between the two RC types. The authors interpreted that the no RT difference in rereading time between SRC and ORC in the HOM construction was due to the result of similar outcomes for the similarity-based interference effect in ORC and the word order–based garden path effect in SRC. With regard to similarity-based interference in an ORC sentence, when appearing in two adjacent items, the same nominative case marker (*–i*/*–ga*) or the same accusative case marker (*–eul*/*–reul*) may import interference, resulting in longer RTs for the first two NPs and for the head noun. This is where integration and interference processing costs occur (Kwon et al., 2010; Nakayama et al., 2005).

The garden path effect in temporarily ambiguous contexts is linked to the experience-based account, which suggests that the more frequent structure is easier to process than a less frequent structure. In an SRC sentence, the first NP is the subject of a matrix sentence and is marked with the nominative case marker, *–ga,* while the second NP is the object of the RC and is marked with the accusative case marker, *–reul*. This order is the typical canonical word order in Korean so that the parser processes it as a simple SOV sentence until they encounter the head noun, where reanalysis and modification may occur. The authors suggested that no RT differences at the head noun position between SRC and ORC may be due to these two independent effects.

While Kwon et al. (2010) interpreted the longer RT at ORCs' head noun position as evidence showing ambiguity is resolved, Mansbridge et al. (2016) hypothesized that structural ambiguity is resolved when the parser recognizes the RC in a sentence, the locus of disambiguation (in Korean) being the RC verb having an adnominal marker.[2] That is, the increased RT at the RC verb, which reflects the *RC surprisal cost,* where the parser recognizes that the sentence contains the RC in Korean can be observable with both SRCs and ORCs. However, the difficulty of processing is more salient in ORCs, since ORC structure is less frequent than SRC. Mansbridge et al. observed RC processing difficulty in Korean adult speakers using an eye-tracking methodology. As compared to SRCs, they found significantly longer go-past RTs (regression path time) at the RC verb in ORCs and at the head noun in ORCs.

In the current study, we examined the RC processing in children with SLI compared to children with TD. Based on previous studies, we considered the RC verb and the head noun as critical regions in HSM constructions and the second NP, the RC verb, and the head noun as critical with HOM. We hypothesized that the increased RTs at those critical regions suggest that the typical morphosyntactic knowledge may be involved in real-time processing of RC sentences in Korean.

In summary, previous research has shown that ORC sentences feature greater processing difficulty as compared with SRC sentences. However, the processing advantage of SRCs over ORCs can be altered by various factors such as linguistic context (e.g., type of NPs or case markers) and type of language (postnominal vs. prenominal). Given that there are cross-linguistic differences between Korean and English and that no study has examined RC processing by measuring online and off-line processing in Korean children, investigating RC sentence processing in children with and without SLI can offer insights into the source of difficulty with RC sentences.

Therefore, in this study, we investigated RC processing in children with and without SLI in Korean. We used an online task measuring the RT for each word in RC sentences and an off-line task evaluating comprehension of the RC sentences. For the online sentence-processing task, we focused particularly on patterns of RT at the critical regions to investigate whether children with SLI would differ from children with TD. The online sentence-processing task would evaluate the use of the morphosyntactic knowledge when processing syntactically complex sentences. Analyzing both data sets provided evidence that may support either the impaired processing account or the syntactic deficit account with regard to the cause of difficulty for children with SLI in processing complex sentences.

Research Questions

The following specific objectives were addressed in order to determine differences between children with SLI and children with TD in processing syntactically complex sentences.

- Are there differences between children with SLI and children with TD regarding RTs (as measured by the real-time processing task) for RC sentences?
- Are there differences between children with SLI and children with TD regarding comprehension accuracy (as measured by the comprehension task) for RC sentences?

If off-line comprehension performance in children with SLI is poorer than in children with TD, children with SLI would have either impaired syntactic knowledge or an impaired processing mechanism for comprehending sentences. In the online processing task, if the patterns of RT on the critical regions in children with SLI were similar but only slower compared to children with TD, it would suggest that children with SLI may use appropriate morphosyntactic knowledge in processing RC sentences, but their processing mechanism is problematic. However, if the patterns of RT on the critical regions were atypical, not just slower, in children with SLI compared to children with TD, it would suggest that the appropriate morphosyntactic knowledge may not be manifest in children with SLI.

Method

Participants

All participants completed standardized tests of language ability (Language Scale for School-Age Children [LSSC]; Lee et al., 2014), vocabulary knowledge (Receptive

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[2]A fact-clause is identical to an RC until the adnominal marker appears in Korean—for instance, the sentence with a fact-clause, "Cat-NOM duck-ACC tie up-AND fact-NOM is.true-Declarative (ENG: The fact that the cat ties up the duct is true)," versus the sentence with an RC (1-c) above. Mansbridge et al. (2016) discussed fact-clauses are less frequently used than RC verb–headed clauses, although the adnominal marker in Korean also indicates the other embedded clause like a fact-clause. Therefore, the expectation of encountering RC structure would be greater with a focus on the RC verb than with the less frequent fact-clause. For details, see Kwon (2008) and Mansbridge et al.

and Expressive Vocabulary Test; Kim et al., 2009), and nonverbal IQ (Kaufman Assessment Battery for Children; Moon & Byun, 1997). Participants were also administered a series of executive functioning (EF) tasks to see if there were differences in the cognitive abilities between the two groups. EF tasks included working memory tasks (backward digit span and backward matrix tasks), an inhibition task (flanker task), and a shifting task (Dimensional Change Card Sort [DCCS] task). There was no difference in performance on EF tasks between the two groups, $F(5, 36) = 1.42$, $p = .24$, Wilk's $\Lambda = 0.84$, partial $\eta^2 = .16$ (see Table 1). The detailed description of each EF task is presented in Appendix A.

Nineteen children with SLI were selected for the SLI group, aged 7;0–10;7 (years;months), and 24 age-matched typically developing children for the TD group aged 7;6–10;7 were recruited for this study. Because the range of children's age varied, we checked the comparability in children's language ability indexed by the LSSC by age in each group. There was no difference in children's language ability (LSSC total language index) by age within each group: $F(3, 23) = 0.84$, $p = .49$, for the TD group and $F(3, 18) = 2.05$, $p = .15$, for the SLI group. Detailed comparisons in the subtests of the LSSC by age within each group were presented in Table 2. The sample size between the two groups was not matched since we included all participants to increase the statistical power and to obtain reliable results. As a result, 10 boys and nine girls were included in the SLI group, and eight boys and 16 girls were included in the TD group. We compared the language ability between boys and girls within each group, and there was no gender difference in LSSC total language index in the TD group, $F(1, 23) = 0.23$, $p = .64$, and in the SLI group, $F(1, 18) = 0.02$, $p = .88$. Also, there was no gender difference in LSSC total language between the two groups, $F(1, 42) = 0.82$, $p = .37$. Since there was no evidence of a gender-related effect on processing RC sentences, the gender of participants was not matched, although it was noted that there are more boys than girls in the group with language disorders.

A child with SLI was defined as having a language quotient, measured by the LSSC, 1 *SD* below the mean (Kang & Yim, 2018) in at least one sublanguage area out of five, including receptive language, expressive language, semantics, syntax, and pragmatics. Nine children were 1 *SD* below the mean in one or two sublanguage areas, and 10 children were 1 *SD* below the mean in more than three sublanguage areas in the SLI group. Although these participants did not have a history of getting speech-language therapy, the failure of identification of children with SLI in the early years of school has known to be common because of use of different diagnostic standards as reported in previous studies (Redmond et al., 2011; Tomblin et al., 1997).

The two groups did not differ in age or nonverbal IQ. However, there was a difference in language ability indexed by the LSSC and in vocabulary knowledge indexed by the Receptive and Expressive Vocabulary Test, with the TD group having better language ability in all of five sublanguage areas and vocabulary knowledge than the SLI group (see Table 3 for detailed information).

Measurement

Language Measurement

The LSSC (Lee et al., 2014) is a norm-referenced test that comprises nine subtests: Category Naming, Antonyms, Synonyms, Sentence Comprehension, Metaphoric Sentence Comprehension, Grammatical Error Judgment and Correction, Production of Complex Sentences, Paragraph Comprehension, and Sentence Repetition. The LSSC was developed to assess the overall language abilities in five language areas, including receptive language, expressive language, semantics, grammar, and pragmatics, and auditory memory of school-age children.

Experimental Measurement

The sentence-processing task was presented using SuperLab 5 software (Cedrus Corporation, 2015).

(1) Sentence-processing task: For the sentence-processing task, 72 sentences, including 48 RC sentences and 24 filler sentences, were created in total. RC sentences were manipulated by two features: syntactic role (either a subject or an object) in a matrix clause and in an RC, which produced four different sentence types. Twenty-four SRC sentences were created, including 12 with the head noun being the subject in the matrix sentence (HSM_SRC: SS) and 12 with the head noun being the object in the matrix sentence (HOM_SRC: OS). Likewise, 24 ORC sentences were created, including

Table 1. Mean and standard error on executive functioning tasks between the typical development (TD) group and the specific language impairment (SLI) group.

Variable	TD group (n = 24) M (SE)	SLI group (n = 19) M (SE)	F	p	Partial η^2
Digit span (arcsine)	0.37 (0.03)	0.31 (0.02)	2.50	.12	.06
Matrix span (arcsine)	0.42 (0.03)	0.35 (0.03)	2.00	.17	.05
Inhibition effect (ms)	66.93 (32.27)	116.45 (33.56)	1.10	.30	.03
Switching accuracy (arcsine)	1.26 (0.06)	1.08 (0.06)	2.99	.09	.07
Switching RT (ms)	1,470.28 (59.85)	1,607.43 (85.34)	2.35	.13	.06

Note. A one-way multivariate analysis of variance with the executive functioning tasks as dependent variables between the TD group and the SLI group was conducted. RT = response time.

Table 2. Language ability by age in each group.

Age group	TD group 7 (*n* = 5)	8 (*n* = 5)	9 (*n* = 10)	10 (*n* = 4)	*F*	SLI group 7 (*n* = 5)	8 (*n* = 5)	9 (*n* = 5)	10 (*n* = 4)	*F*
LSSC total lang index	102.8 (3.4)	109 (5.6)	102 (10.2)	104.8 (9.6)	0.84	79.2 (9.2)	76.6 (3.9)	86 (4.0)	80.25 (6.1)	2.05
LSSC recept lang index	104.8 (6.8)	108.2 (8.3)	105.2 (10.1)	105 (9.6)	0.16	82.2 (10.2)	77.8 (5.6)	87.4 (8.4)	80.75 (5.1)	1.33
LSSC expre lang index	100.6 (5.2)	108.8 (3.4)	99.2 (10.3)	104.3 (9.3)	1.64	78.2 (9.0)	77 (7.8)	85.6 (3.9)	81.5 (7.6)	1.40
LSSC seman index	100.4 (6.7)	106.6 (6.2)	99.7 (11.0)	103.5 (14.1)	0.60	76.8 (10.8)	77.4 (5.3)	85.4 (5.0)	84.25 (7.3)	1.74
LSSC syntax index	106.4 (7.1)	109.2 (7.8)	104 (10.9)	107.5 (3.9)	0.43	83.6 (7.9)	78.6 (10.3)	88.8 (11.7)	79 (7.3)	1.20
LSSC prag index	99 (7.4)	112 (14.4)	103.5 (11.1)	98.75 (12.5)	1.41	89 (8.2)	82 (12.0)	88 (8.4)	83.75 (9.5)	0.59

Note. TD = children with typical development; SLI = children with specific language impairment; LSSC = Language Scale for School-Age Children; lang = language; recept = receptive; expre = expressive; seman = semantic; prag = pragmatic.

12 with the head noun being the subject in the matrix sentence (HSM_ORC: SO) and 12 with the head noun being the object in the matrix sentence (HOM_ORC: OO). See Table 4 for an example of each sentence type. Since the current study was to examine the syntactic feature of RC sentence processing, the influence of lexical–semantic features on the processing of RC sentences was controlled to minimize potential difficulty with word retrieval as much as possible. To avoid potential confounds (e.g., inanimate noun effect on sentence comprehension), all nouns in each sentence were animals. Also, to minimize the lexical bias between nouns and verbs (e.g., Wells et al., 2009), a typical semantic relationship between the noun (e.g., “goat”) and the verb (e.g., “hold”) was avoided in each sentence. To make the sentence simpler (e.g., Mansbridge et al., 2016) and to match the number of words across the four sentence types, each sentence was composed of five words, including three nouns and two verbs. Eighteen nouns and six verbs were used to construct the four sentence types. For nouns, 18 animal nouns were selected: 6 one-syllable nouns, *so* (“cow”), *dalg* (“chicken”), *gae* (“dog”), *yang* (“sheep”), *sae* (“bird”), *mal* (“horse”); 6 two-syllable nouns, *tokki* (“rabbit”), *saseum* (“deer”), *dwaeji* (“pig”), *yeomso* (“goat”), *oli* (“duck”), *yeou* (“fox”); and 6 three-syllable nouns, *goyangi* (“cat”), *kokkiri* (“elephant”), *goebugi* (“turtle”), *wonsungi* (“monkey”), *gaeguri* (“frog”), *gileogi* (“goose”). The frequency of the nouns in the three noun positions within each sentence type was matched across the sentence types based on the frequency of modern Korean word usage, $F(17, 2) = 15.5$, $p = .998$ (National Institute of Korean Language, 2005). An example of the frequency of the word in noun positions for each sentence is provided in Appendix B. Also, one noun of each syllable length was

Table 3. Participants’ characteristics.

Variable	TD group (*n* = 24) *M* (*SD*)	Range	SLI group (*n* = 19) *M* (*SD*)	Range	*t*	Cohen’s *d*
Age	9.13 (0.90)	7;6–10;7	8.84 (1.08)	7;0–10;7	0.97	
Nonverbal IQ[a]	106.96 (9.31)	90–131	103.95 (8.32)	86–116	1.10	
Receptive vocabulary (raw score)[b]	106.33 (15.30)	70–140	89.47 (14.47)	64–123	3.67**	1.13
Expressive vocabulary (raw score)[b]	108.08 (16.07)	87–139	90.37 (14.33)	69–133	3.76**	1.13
LSSC total language index[c]	104.08 (8.25)	91–122	80.53 (6.71)	65–91	10.08**	3.13
LSSC receptive language index	105.71 (8.57)	89–122	82.11 (7.97)	67–101	9.24**	2.85
LSSC expressive language index	102.33 (8.63)	87–121	80.53 (7.50)	66–91	8.71**	2.70
LSSC semantic index	101.92 (9.78)	85–123	80.79 (7.92)	63–94	7.64**	2.37
LSSC syntax index	106.17 (8.51)	91–128	82.68 (9.73)	69–103	8.43**	2.57
LSSC pragmatic index	103.54 (11.75)	85–125	85.79 (9.32)	70–95	5.38**	1.67

Note. Values are presented as mean and standard deviation. TD = children with typical development; SLI = children with specific language impairment.

[a]Korean Kaufman Assessment Battery for Children (Moon & Byun, 1997). [b]Receptive and Expressive Vocabulary Test (Kim et al., 2009). [c]Language Scale for School-Age Children (Lee et al., 2014).

$^{**}p < .01$.

Table 4. Regions of interest in HSM and HOM constructions.

HSM construction	Region 1	Region 2 (verb in RC)	Region 3 (head noun)	Region 4	Region 5
HSM_SRC: SS	goyangi-reul cat-ACC	**mu-neun** **bite-ADN**	**gae-ga** **dog-NOM**	ori-reul duck-ACC	mukkeoyo ties up
English	The dog that bites the cat ties up the duck				
HSM_ORC: SO	goyangi-ga cat-NOM	**mu-neun** **bite-ADN**	**gae-ga** **dog-NOM**	ori-reul duck-ACC	mukkeoyo ties up
English	The dog that the cat bites ties up the duck				
HOM construction	**Region 1**	**Region 2**	**Region 3 (verb in RC)**	**Region 4 (head noun)**	**Region 5**
HOM_SRC: OS	gae-ga dog-NOM	**goyangi-reul** **cat-ACC**	**mu-neun** **bite-ADN**	**ori-reul** **duck-ACC**	mukkeoyo ties up
English	The dog ties up the duck that bites the cat				
HOM_ORC: OO	gae-ga dog-NOM	**goyangi-ga** **cat-NOM**	**mu-neun** **bite-ADN**	**ori-reul** **duck-ACC**	mukkeoyo ties up
English	The dog ties up the duck that the cat bites				

Note. Regions of interest are bolded. RC = relative clause; SRC = subject relative clause; ORC = object relative clause.

used for constructing a sentence. For verbs, six verbs (*carry, tie, hold, hug, bite,* and *hit*) from verb stimuli used in the previous study (Park & Lee, 2009) were selected and were used 4 times for each sentence type for a verb in the RC and the matrix sentence. In constructing the six RC sentences in each RC type, six verbs were paired into three sets, making three RC sentences in each RC type (e.g., *carry–hit, tie–hold,* and *hug–bite*). Then, the position of one side of the verb was moved up by one cell, and the order of the paired verb set was reversed (e.g., hold–carry, bite–tie, and hit–hug), making another three RC sentences in each RC type. To construct the other six RC sentences in each RC type, the order of verbs in those six paired verb sets was reversed, resulting in a total of 12 RC sentences to be made. Besides the target sentences, 24 simple compound sentences served as filler sentences (e.g., 12 simple sentences for Block A and another 12 simple sentences for Block B); these were excluded from the final analyses. For the filler sentence, the number of words in a sentence was matched to the RC sentences, so that the filler sentence was composed of five words with three nouns and two verbs as well. The meaning of the filler sentences did not overlap with the meanings used in RC sentences (e.g., *The cat bites the duck and ties up the dog*.). Although 18 nouns and six verbs were used to construct experimental sentences, the nouns and the verbs were shifted among their position, so that a sentence with the same meaning across RC and filler sentences was not created. Because we used familiar words repeatedly and the frequency of words was matched across word positions, it is unlikely that the lexical–semantic knowledge would affect children's performance on the sentence-processing task.

The 72 sentences were divided into two blocks, with each block containing 36 sentences (24 RC sentences and 12 filler sentences). The number of sentence types including filler sentences was matched across blocks. Two blocks were counterbalanced so that half the children read one block first, and the rest of the children read the other block first. The presentation of sentences was randomized within blocks for each participant. Between two blocks, participants took a break of around 5–10 min. Participants were told that they would get a gift if they completed the task with good attention to avoid losing their motivation during the task.

The sentence-processing task consisted of two parts. Children were asked to read each sentence (online task), and the comprehension task was presented after reading each sentence (off-line comprehension task).

(1-1) Online task: A *self-paced reading* (SPR) and moving window technique (e.g., King & Just, 1991) was adopted so that words appeared on the computer screen one at a time from left to right. Participants were asked to read each word that appeared on the screen using SPR, and they were asked to press the space bar to bring up the next word. The response times for each word were collected. The analyses were focused on critical regions. As we specified earlier, the RC verb and the head noun were considered as critical regions in the HSM construction, and the second NP, the RC verb, and the head noun were considered as critical regions in the HOM construction. Consideration of the second NP was based on the similarity-based account, the RC verb was based on the experience-based account in ORCs, and the head noun was based on structural integration cost and similarity-based processing costs in ORCs and on garden path effect costs in SRCs (see Table 4).

(1-2) Off-line comprehension task: For the off-line comprehension task, 160 pictures including target and filler pictures were prepared: 112 for RC sentences and 48 for filler sentences. A set of four pictures was presented right after participants read each sentence, and participants were asked to press the number of the target picture on the keyboard corresponding to the sentence that they had read. The filler pictures were created by exchanging the subject and the object in the matrix sentence, by exchanging the subject and the object in the RC, and by exchanging two verbs in a sentence (an example of four pictures used in the off-line comprehension task is presented in Appendix C). For the off-line comprehension task, the accuracy and RT for each sentence were collected.

Coding Procedures and Data Analyses

We analyzed effects on RT of the online and off-line sentence processing with linear mixed-effects (LME) models and effects on accuracy of the off-line sentence-processing (comprehension) task with a generalized linear mixed-effects (GLME) model, using *lme4* package (D. M. Bates et al., 2015) in R (R Core Team, 2017). The LME model was adopted because it considers both fixed variables (group and RC type) and random variables (participant-related factors and sentence-related factors), unlike the simple linear model. That is, via the LME model, any individual differences and sentence-related variations that might affect the RTs during reading can be considered in a model. We used LME for RT of online sentence processing because the dependent variable is continuous, while we used GLME for the off-line sentence comprehension task because the dependent variable is binary. For the online processing data, three different analyses were conducted: one for the RT from correctly answered sentences on the comprehension task (correct RT), another for the RT from incorrectly answered sentences to the comprehension task (incorrect RT), and the other for the comparisons between correct RT and incorrect RT.

Online Processing: Correct RT

For the online sentence-processing data, two separate analyses were conducted, one was at each word position and the other was between two adjacent word positions to capture the participants' full RT patterns.

1. For analyses at each word position, RT at each region (our analyses focused on the areas of interest) was the response variable; RC type, group, and their interaction were entered as the fixed effects; and the subject and the sentence item were entered as the random effects. A separate model was built depending on the roles of the head noun in the matrix sentence, which were HSM sentences and HOM sentences, following the previous study (Kwon et al., 2010). Since not only the positions of head nouns and RC verbs but also the linguistic properties before head nouns or RC verbs were different between two RC sentence constructions (HSM vs. HOM), the linguistic processing differed between two RC constructions. Hence, separate analyses were decided upon. For the group contrasts code, we used −0.5 for the SLI group and 0.5 for the TD group. We also used −0.5 for OS and 0.5 for OO in the HOM sentences, as well as −0.5 for SO and 0.5 for SS in HSM sentences for the RC type contrasts code. For the RT analyses, only the RTs for the sentences on which participants responded correctly during the comprehension phase were retained. The RT data were log-transformed and trimmed by removing ±2 *SD*s below and above the residuals in the predicted model.

$$\text{RT Model} = \log(\text{RT}) \sim \text{Group}\tilde{n}\text{RC Type} + (1|\text{Participant}) + (1|\text{Item})$$

2. For analyses between two adjacent word positions, RT was the response variable; group, word position, and their interaction were entered as the fixed effects; and the subject and the word item were entered as the random effects. For the word position contrasts code between two words, we used −0.5 for the preceding word and 0.5 for the following word (e.g., −0.5 for Word 1 and 0.5 for Word 2). All words except the final word, Word 5, in a sentence were included for the word position since most of the integration was completed before Word 5. The RT was not log-transformed in this model to capture the exact RT differences between two words if any. Instead, the RT data were trimmed by removing ±2 *SD*s below and above the mean RTs at each word position in each sentence type for each participant.

$$\text{Comparison Model} = \text{RT} \sim \text{Group} \times \text{Word Position} + (1|\text{Participant}) + (1|\text{Word})$$

Online Processing: Incorrect RT

For the error analyses, the RT data from the incorrect answers to the comprehension questions were used. The coding procedures and data analyses were the same as the ones used above.

Online Processing: Between Correct RT and Incorrect RT

The separate analysis of variance between correct RT and incorrect RT was conducted in each sentence type for each group to examine whether the RT processing would be similar between correct RT and incorrect RT in each group.

Off-line Comprehension Task

For comprehension, the binary outcome (accuracy) was coded as "0" for an incorrect response and "1" for a correct response and then entered as a response variable. The RC type, group, and their interaction were entered as fixed effects, while the subjects and the sentence items were entered as random effects.

$$\text{Accuracy Model} = \text{Accuracy} \sim \text{Group} \times \text{RC Type} + (1|\text{Participant}) + (1|\text{Item})$$

All proportional accuracy data from the off-line sentence comprehension task were transformed using an arcsine transformation. The RT data from the online sentence-processing task were trimmed by removing ±2 *SD*s below and above the mean RTs at each critical region in each group, and the RT data from the off-line sentence comprehension task were trimmed by removing ±2 *SD*s below and above the mean RT in each group for correlational analyses.

Results

Online Processing: Correct RT

Separate LME models for the HSM sentences and the HOM sentences were built, and the *p* value of the estimated coefficient was obtained using the *lmerTest* package.

Analyses at Each Word Position

HSM sentence. As shown in Table 5, for the HSM sentences, LME model results showed that there was no main effect of group or RC type and no interaction between group and RC type at two regions of interest, at Word 2 and at Word 3. Both the TD group and the SLI group read at Word 2 and Word 3 between the SS type and the SO type with a similar reading rate (see Table 5). See the visual presentation of the RT for each word position in the HSM sentences between the TD group and the SLI group in Figure 1.

HOM sentence. The LME model for the HOM sentences showed that any effects of group or RC type were not significant at Word 2. However, there was a marginally significant interaction between Group × RC Type, although it did not reach significance. The follow-up analyses were conducted by reanalyzing the model having each group or each RC type as a reference group/sentence separately. Results showed that there was no effect of RC type when the SLI group was set as a reference group, $t = -1.27$, $p = .20$, while there was a significant effect of RC type when the TD group was set as a reference group, $t = -5.078$, $p < .001$, indicating the TD group was slower in the OO type than in the OS type at Word 2. At Word 3, there was an interaction of group and RC type, but there was no effect of group (see Table 6). The follow-up analyses yielded a significant difference between the OO type and the OS type when the SLI group was set as a reference group, $t = 2.04$, $p < .05$. It indicated that the SLI group was slower at Word 3 in the OS type ($M_{\text{raw score}}$ = 1,518.90 ms, *SE* = 258.248) than in the OO type ($M_{\text{raw score}}$ = 1,247.33 ms, *SE* = 142.00). However, with the TD group being a reference group, there was no difference between the OO type and the OS type, $t = -0.66$, $p = .51$, indicating that the TD group read at Word 3 with a similar reading rate between the OO type ($M_{\text{raw score}}$ = 1,618.23 ms, *SE* = 156.70) and the OS type ($M_{\text{raw score}}$ = 1,537.51 ms, *SE* = 170.48). In addition, there was no difference between the TD group and the SLI group when the OS type ($t = 0.55$, $p = .59$) or the OO type ($t = 1.84$, $p = .07$) was set as the reference. Together, these results indicate that the interaction observed at Word 3 was driven by the significant difference between the OO type and the OS type only in the SLI group, but the TD group read at Word 3 with a similar reading rate between the OO type and the OS type. Also, the main effect of the RC type was found at Word 4, indicating that the reading rate at Word 4 was faster in the OO type than in the OS type in both groups as shown in Figure 2.

Table 5. Linear mixed-effects model estimates and *t* values for Word 2 and Word 3 in HSM sentence.

Variable	Est. (β)	*SE*	*t*	*p*
Word 2: mu-neun (bit-ADN)				
Group	0.042	0.124	0.343	.733
RC type	−0.022	0.054	−0.407	.684
Group × RC Type	0.108	0.064	1.688	.092
Word 3: gae-ga (dog-NOM)				
Group	0.213	0.146	1.460	.150
RC type	0.011	0.072	0.145	.885
Group × RC Type	−0.063	0.088	−0.715	.475

Note. RC = relative clause.

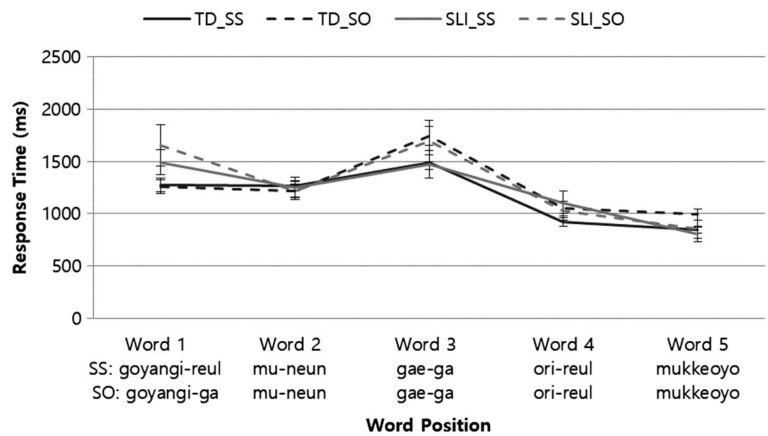
Analyses Between Adjacent Words

HSM sentence. LME analyses between two adjacent words (Word 1 vs. Word 2) and group (TD vs. SLI) in the SS type revealed that there was a significant interaction between group and word position. Follow-up analyses were conducted by centering each group variable separately and rerunning the model. When the TD group was set as a reference, there was no RT difference between Word 1 and Word 2, while there was a significant RT difference between two words, with the RT at Word 2 being 247.19 ms faster than the RT at Word 1 when the SLI group was set as a reference, $t = -2.44$, $p < .05$. Also, there was a main effect of word position in Word 2 versus Word 3, with overall participants taking about 235.07 ms longer to respond to Word 3 compared to Word 2. Similarly, in Word 3 versus Word 4, there was a main effect of word position, with overall participants taking about 470.76 ms faster to respond to Word 4 compared to Word 3.

In the SO type, a significant main effect of word position and an interaction between group and word position were found in Word 1 versus Word 2. The main effect of word position in Word 1 versus Word 2 indicates that overall participants took about 235.07 ms longer to respond to Word 1 compared to Word 2. Follow-up analyses were conducted to find the locus of interaction. When each group was set as a reference group, there was no significant main effect of word position. However, when Word 1 was set as a reference position, there was a significant effect of group, $t = -2.27$, $p < .05$, indicating that the TD group was about 625.57 ms faster than the SLI group at Word 1, while no significant main effect of group was observed when Word 2 was set as a reference position. These results indicated that the observed RT difference between groups being present only at Word 1, but not at Word 2, drove the significant Group × Word Position interaction. Like in the SS type, there was also a main effect of word position in Word 2 versus Word 3, with overall participants taking about 484.85 ms longer to respond to Word 3 compared to Word 2. Similarly, in Word 3 versus Word 4, there was a main effect of word position, with overall participants taking about 662.71 ms faster to respond to Word 4 compared to Word 3. See Table 7 for the detailed results of these analyses.

HOM sentence. LME analyses between two adjacent words (Word 1 vs. Word 2) and group (TD vs. SLI) in the OS type yielded a significant interaction of Group × Word Position. To find a locus of an interaction, follow-up analyses were conducted by centering each group variable separately

Figure 1. Correct response time to each word in the HSM sentences. TD = children with typical development; SLI = children with specific language impairment.



and rerunning the model. When the TD group was set as a reference group, the effect of word position was significant, $t = 2.26$, $p < .05$, showing that the TD group was about 207.87 ms slower at Word 2 than at Word 1 while the SLI group was about 346.78 ms faster at Word 2 than at Word 1 when the SLI group was set as a reference group, $t = -2.46$, $p < .05$. These results indicate that the interaction of Group × Word Position was driven by the opposite direction of increase and decrease in RTs at Word 1 and Word 2 between two groups. However, in Word 2 versus Word 3, and Word 3 versus Word 4, neither a main effect nor an interaction between group and word position was found.

In the OO type, there was a significant interaction between group and word position (Word 1 vs. Word 2). Follow-up analyses in the model centered on the TD group revealed that an effect of word position was significant, $t = 3.77$, $p < .001$, showing that the TD group was about 406.94 ms slower at Word 2 than at Word 1 while an effect of word position was not significant when the SLI group was centered in the model. These results indicate that the significant difference in RTs between Word 1 and Word 2 in the TD group, as well as the comparable RTs between these two words in the SLI group, drove a significant interaction between group and word position. While there was no effect or interaction in Word 2 versus Word 3, a significant main effect of word position and an interaction between group and word position were found in Word 3 versus at Word 4. The main effect of word position showed that overall participants were about 384.16 ms faster to read at Word 4 than at Word 3. Follow-up analyses were conducted to find the locus of interaction with each group as a reference group. When the TD group was set as a reference group, the effect of word position was significant, $t = -6.06$, $p < .001$, showing that the TD group was about 639.32 ms faster to read at Word 4 than at Word 3 while an effect of word position was not significant when the SLI group was set as a reference group, $t = -0.89$, $p = .39$. These results indicated that the significant difference in RTs between Word 3 and Word 4 in the TD group, as well as the comparable RTs between these two words in the SLI group, drove a significant

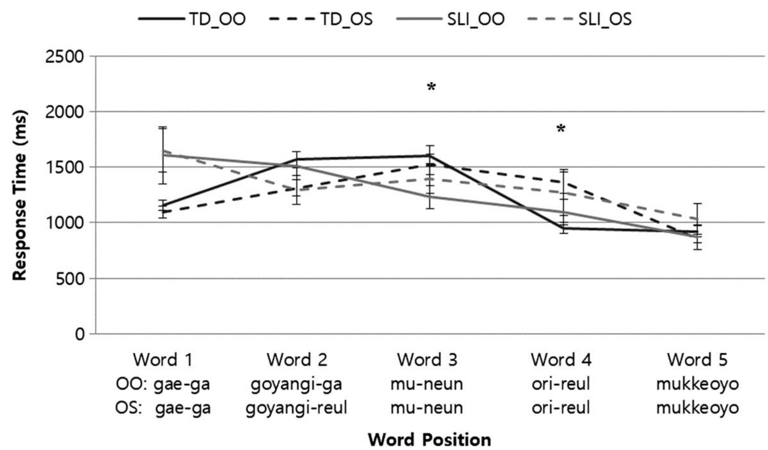
Table 6. Linear mixed-effects model estimates and *t* values for Word 2, Word 3, and Word 4 in HOM sentence.

Variable	Est. (β)	*SE*	*t*	*p*
Word 2: goyangi-ga (OO), goyangi-reul (OS)				
Group	0.014	0.134	0.103	.918
RC type	0.089	0.070	1.273	.204
Group × RC Type	0.140	0.083	1.675	.095
Word 3: mu-neun (bite-ADN)				
Group	0.087	0.159	0.545	.589
RC type	−0.170	0.083	−2.040	.043*
Group × RC Type	0.205	0.097	2.120	.035*
Word 4: ori-reul (duck-ACC)				
Group	0.023	0.123	0.186	.853
RC type	−0.205	0.074	−2.793	.006**
Group × RC Type	−0.018	0.085	−0.211	.833

Note. RC = relative clause.

*$p < .05$. **$p < .01$.

Figure 2. Correct response time to each word in the HOM sentences. TD = children with typical development; SLI = children with specific language impairment.



interaction between Group × Word Position. See Table 7 for the detailed results of these analyses.

Online Processing: Incorrect RT

Error Analyses at Each Word Position

HSM sentence. LME model results indicated that there was a significant main effect of sentence type at Word 2 ($t = 2.12$, $p < .05$), indicating that overall participants read at Word 2 faster in the SO type ($M_{\text{raw score}} = 1{,}151.15$ ms, $SE = 827.88$) than in the SS type ($M_{\text{raw score}} = 1{,}316.59$ ms, $SE = 1{,}225.00$). However, there was no main effect of group or interaction at Word 2. Similarly, at Word 3 and Word 4, there was no main effect or interaction, indicating that overall participants read at Word 3 and Word 4 between the SS type and the SO type with similar reading rates (see Figure 3).

HOM sentence. LME model results showed that there was a significant main effect of sentence type in the positive direction at Word 2 ($t = 3.80$, $p < .01$) and Word 3 ($t = 2.18$, $p < .05$). These results indicate that overall participants read faster in the OS type ($M_{\text{raw score}} = 1{,}353.63$ ms, $SE = 861.32$ at Word 2 and $M_{\text{raw score}} = 1{,}341.21$ ms, $SE = 1{,}008.60$ at Word 3) than in the OO type ($M_{\text{raw score}} = 1{,}589.19$ ms, $SE = 1{,}073.19$ at Word 2 and $M_{\text{raw score}} = 1{,}401.01$ ms, $SE = 997.11$ at Word 3), both at Word 2 and Word 3. There was also a significant main effect of sentence type at Word 4 in the negative direction ($t = -4.41$, $p < .001$), indicating that overall participants read faster in the OO type ($M_{\text{raw score}} = 1{,}011.97$ ms, $SE = 868.647$) than in the OS type ($M_{\text{raw score}} = 1{,}328.94$ ms, $SE = 2{,}008.32$) at Word 4. Neither a main effect of group nor an interaction of Group × Sentence Type at each word position was found (see Figure 4).

Error Analyses Between Adjacent Words

HSM sentence. LME analyses between two adjacent words (Word 1 vs. Word 2) and group (TD vs. SLI) in the SS type yielded a significant interaction of Group × Word Position. Follow-up analyses were conducted by centering each group variable separately and rerunning the model. There was a significant main effect of word position in the SLI group, $t = -2.89$, $p < .01$, while the main effect of word position was marginally significant in the TD group, $t = 1.87$, $p = .06$. The SLI group read about 516.58 ms faster at Word 2 compared to one at Word 1. There was a trend that the TD group read about 418.69 ms slower at Word 2 compared to one at Word 1. The interaction between Group × Word Position seemed to be driven by the different direction in RTs from Word 1 to Word 2 between the two groups. Also, while neither a main effect of the two variables nor an interaction was found in Word 2 versus Word 3, there was a significant main effect of word position in the negative direction in Word 3 versus Word 4, indicating that overall participants read faster at Word 4 than at Word 3.

In the SO type, a significant interaction of Group × Word Position was found in Word 1 versus Word 2. Follow-up analyses with each group being set as a reference group yielded a significant main effect of word position in the negative direction only in the SLI group, $t = -2.13$, $p < .05$, indicating that the SLI group read around 193.20 ms faster at Word 2 than at Word 1 while the TD group read at Word 1 and Word 2 with similar reading rates, $t = 1.02$, $p = .31$. Similarly, in Word 2 versus Word 3, there was a significant interaction between group and word position. Follow-up analyses revealed that there was a main effect of word position when the TD group was set as the reference group, $t = 2.87$, $p < .01$, while there was no main effect of word position when the SLI group was set as the reference group, $t = 0.58$, $p = .57$. The interaction effect was driven by the fact that the TD group read around 452.01 ms slower at Word 3 than at Word 2 while the SLI group read with a similar reading rate both at Word 2 and at Word 3. In Word 3 versus Word 4, a significant main effect of word position was found in the negative direction, indicating that overall participants

Table 7. Linear mixed-effects model estimates and *t* values in adjacent words and groups for each sentence type with response time from the correctly answered sentence to the comprehension question.

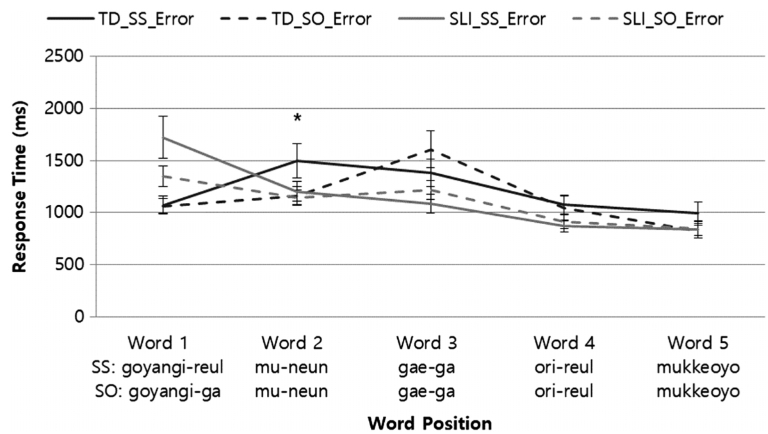
Sentence type	Words	Variable	Est. (β)	*SE*	*t*
SS	W1 vs. W2	Group	−69.77	190.29	−0.367
		Word position	−121.32	61.82	−1.962
		Group × Word Position	251.75	123.65	2.036*
	W2 vs. W3	Group	86.806	180.318	0.481
		Word position	235.071	97.649	2.407*
		Group × Word Position	0.296	136.553	0.002
	W3 vs. W4	Group	−66.49	156.52	−0.425
		Word position	−470.76	77.02	−6.112***
		Group × Word Position	−204.47	151.82	−1.347
	W4 vs. W5	Group	−83.05	104.28	−0.796
		Word position	−182.14	62.13	−2.932*
		Group × Word Position	225.37	111.72	2.017*
SO	W1 vs. W2	Group	−425.53	262.35	−1.622
		Word position	−233.67	83.96	−2.783**
		Group × Word Position	400.08	167.91	2.383*
	W2 vs. W3	Group	−0.732	221.029	−0.003
		Word position	484.847	107.6327	4.505***
		Group × Word Position	36.5382	188.299	0.194
	W3 vs. W4	Group	4.022	208.254	0.019
		Word position	−662.712	100.216	−6.613***
		Group × Word Position	−31.966	189.949	−0.168
	W4 vs. W5	Group	38.73	126.89	0.305
		Word position	−114.89	58.83	−1.953
		Group × Word Position	120.22	117.66	1.022
OO	W1 vs. W2	Group	−260.33	239.43	−1.087
		Word position	164.50	97.24	1.692
		Group × Word Position	484.88	193.16	2.510*
	W2 vs. W3	Group	230.57	200.10	1.152
		Word position	−132.50	91.88	−1.442
		Group × Word Position	313.16	174.59	1.794
	W3 vs. W4	Group	48.89	187.62	0.261
		Word position	−384.16	98.51	3.900**
		Group × Word Position	−510.30	160.62	−3.177**
	W4 vs. W5	Group	−144.73	142.56	−1.015
		Word position	−128.54	84.20	−1.527
		Group × Word Position	193.15	131.76	1.466
OS	W1 vs. W2	Group	−313.97	222.56	−1.411
		Word position	−69.46	84.20	0.825
		Group × Word Position	554.65	168.40	3.294**
	W2 vs. W3	Group	61.83	227.13	0.272
		Word position	154.41	88.50	1.745
		Group × Word Position	100.48	171.12	0.587
	W3 vs. W4	Group	93.56	235.92	0.397
		Word position	−140.22	111.76	−1.255
		Group × Word Position	−22.32	219.50	−0.102
	W4 vs. W5	Group	−64.98	198.78	−0.327
		Word position	−366.19	100.31	−3.651***
		Group × Word Position	−274.49	200.62	−1.368

*$p < .05$. **$p < .01$. ***$p < .001$.

read faster at Word 4 than at Word 3 (see Table 8 for detailed results of these analyses). *HOM sentence* LME analyses between group (TD vs. SLI) and word position (two nearby words) in the OS type yielded neither main effects nor an interaction between the two variables, except there was a marginally significant interaction between group and word position in Word 3 versus Word 4.

In the OO type, there was a significant main effect of word position in Word 1 versus Word 2, indicating that overall participants read slower at Word 2 than at Word 1. In Word 2 versus Word 3, a significant interaction between group and word position was found. Follow-up analyses, with each group being set as a reference group, yielded a significant main effect of word position in the negative direction only in the SLI group, $t = -2.75$, $p < .05$, indicating that the interaction was driven by the fact that the SLI group read around 318.97 ms faster at Word 3 than at Word 2 while the TD group read at Word 2 and Word 3 with similar reading rates, $t = -0.06$, $p = .95$. In Word 3 versus Word 4, a significant main effect of word position and an interaction between group and word position were found. Overall participants read faster at Word 4 than at Word 3. Follow-up

Figure 3. Incorrect response time to each word in the HSM sentences. TD = children with typical development; SLI = children with specific language impairment.



analyses, with each group being set as a reference group, yielded a significant main effect of word position in the negative direction in the TD group, $t = -5.79$, $p < .001$, and a significant main effect of word position in the negative direction in the SLI group, $t = -2.27$, $p < .05$. The TD group read around 614.41 ms faster at Word 4 than at Word 3, and the SLI group read around 214.34 ms faster at Word 4 than at Word 3 (see Table 8 for detailed results of these analyses).

Online Processing: Between Correct RT and Incorrect RT

Analyses revealed that, in the HSM construction, there were no significant differences between the correct RT and the incorrect RT, except that the correct RT took longer than the incorrect RT at Word 3 in both RC types in the SLI group. Similarly, in the HOM construction, there were no significant differences between the correct RT and the incorrect RT in both RC types for each group, except that the correct RT took longer than the incorrect RT at Word 3 in the OS type in the TD group (see Table 9).

Off-line Comprehension Task

Accuracy in HSM sentence. For accuracy for the HSM sentences, GLME model results revealed a main effect of group, $z = 3.335$, $p < .01$ (see Table 10). The accuracies were higher for the TD group than for the SLI group, both in SS ($M_{\text{TD group raw score}} = 0.81$, $SE_{\text{TD group}} = 0.04$; $M_{\text{SLI group raw score}} = 0.47$, $SE_{\text{SLI group}} = 0.06$; $z = 4.767$, $p < .01$) and in SO ($M_{\text{TD group raw score}} = 0.67$, $SE_{\text{TD group}} = 0.05$; $M_{\text{SLI group raw score}} = 0.44$, $SE_{\text{SLI group}} = 0.05$; $z = 3.369$, $p < .01$).

Accuracy in HOM sentence. Similarly, for the accuracy of the HOM sentences, GLME model results revealed

Figure 4. Incorrect response time to each word in the HOM sentences. TD = children with typical development; SLI = children with specific language impairment.

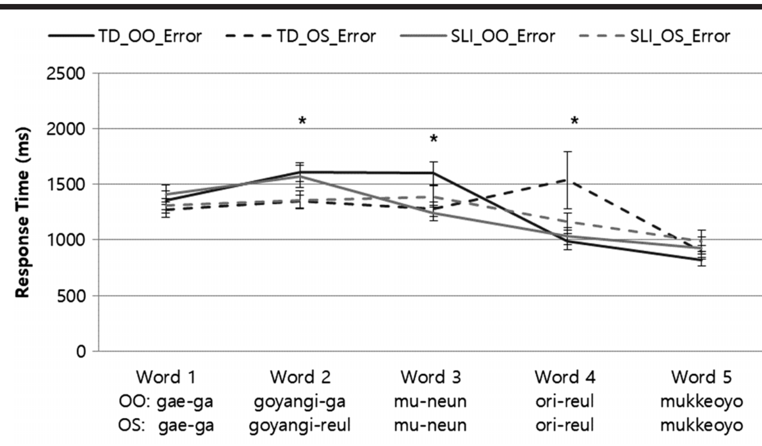


Table 8. Linear mixed-effects model estimates and *t* values in adjacent words and groups for each sentence type with response time from the incorrectly answered sentence to the comprehension question.

Sentence type	Words		Est. (β)	*SE*	*t*
SS	W1 vs. W2	Group	–208.84	251.54	–0.83
		Word position	–48.95	143.40	–0.34
		Group × Word Position	935.28	286.81	3.26**
	W2 vs. W3	Group	212.80	263.97	0.81
		Word position	–113.60	101.16	–1.12
		Group × Word Position	15.88	202.33	0.08
	W3 vs. W4	Group	199.78	205.32	0.97
		Word position	–242.70	87.22	–2.78**
		Group × Word Position	–73.81	161.78	–0.46
	W4 vs. W5	Group	130.96	178.74	0.73
		Word position	–48.31	72.78	–0.66
		Group × Word Position	–47.55	141.12	–0.34
SO	W1 vs. W2	Group	–115.28	168.65	–0.68
		Word position	–45.05	68.03	–0.66
		Group × Word Position	296.30	136.07	2.18*
	W2 vs. W3	Group	186.62	218.80	0.85
		Word position	267.64	121.45	2.20
		Group × Word Position	368.74	177.21	2.08*
	W3 vs. W4	Group	314.93	249.12	1.26
		Word position	–428.97	95.77	–4.48***
		Group × Word Position	–271.47	191.54	–1.42
	W4 vs. W5	Group	125.88	190.28	0.66
		Word position	–149.91	67.42	–2.22*
		Group × Word Position	–151.19	134.85	–1.12
OO	W1 vs. W2	Group	–102.30	202.99	–0.51
		Word position	192.49	77.76	2.48*
		Group × Word Position	111.15	152.34	0.73
	W2 vs. W3	Group	110.94	193.55	0.57
		Word position	–163.45	93.87	–1.74
		Group × Word Position	311.05	155.55	2.00*
	W3 vs. W4	Group	57.02	181.55	0.314
		Word position	–412.38	70.81	–5.82***
		Group × Word Position	–396.08	141.62	–2.80**
	W4 vs. W5	Group	–138.42	172.78	–0.80
		Word position	–134.45	67.24	–2.00*
		Group × Word Position	–66.83	134.48	–0.50
OS	W1 vs. W2	Group	–56.87	151.72	–0.38
		Word position	57.51	60.10	0.96
		Group × Word Position	33.68	120.20	0.28
	W2 vs. W3	Group	–84.49	169.86	–0.50
		Word position	–21.28	68.94	–0.31
		Group × Word Position	–77.47	137.87	–0.56
	W3 vs. W4	Group	220.51	283.71	0.78
		Word position	17.78	121.17	0.15
		Group × Word Position	468.55	242.33	1.93
	W4 vs. W5	Group	220.05	267.93	0.82
		Word position	–409.93	122.31	–3.35***
		Group × Word Position	–466.46	244.61	–1.91

*$p < .05$. **$p < .01$. ***$p < .001$.

a main effect of group, $z = 3.023$, $p < .01$ (see Table 11). The accuracies were higher for the TD group than for the SLI group, both in OO ($M_{\text{TD group raw score}} = 0.59$, $SE_{\text{TD group}} = 0.07$; $M_{\text{SLI group raw score}} = 0.34$, $SE_{\text{SLI group}} = 0.06$; $z = 2.854$, $p < .01$) and in OS ($M_{\text{TD group raw score}} = 0.57$, $SE_{\text{TD group}} = 0.07$; $M_{\text{SLI group raw score}} = 0.31$, $SE_{\text{SLI group}} = 0.05$; $z = 2.996$, $p < .01$).

RT in HSM and HOM sentences. In the RTs for the off-line comprehension task, there was no effect of group or RC type and no interaction of group and RC type in both the HSM sentences (see Table 12) and the HOM sentences (see Table 13).

Discussion

This study examined how children with SLI, compared to children with TD, process complex sentences using RC sentences with different grammatical head nouns. Children's processing was compared for SRC and ORC in HSM and HOM sentences. In order to disentangle the

Table 9. Comparisons between correct response time (RT) and incorrect RT in each sentence type for each group.

Sentence type	Word position	TD group Correct RT M (SE)	TD group Incorrect RT M (SE)	TD group F	SLI group Correct RT M (SE)	SLI group Incorrect RT M (SE)	SLI group F
SS	W2	1,268.20 (48.20)	1,496.47 (164.39)	3.21	1,248.88 (100.27)	1,203.60 (96.81)	0.10
	W3	1,492.63 (70.02)	1,382.08 (133.78)	0.62	1,473.29 (130.95)	1,085.16 (92.23)	6.19*
	W4	918.18 (40.32)	1,075.18 (95.21)	3.21	1,099.20 (119.80)	867.30 (56.82)	3.46
SO	W2	1,219.99 (62.08)	1,163.56 (82.46)	0.30	1,221.11 (83.54)	1,141.36 (73.39)	0.51
	W3	1,742.28 (91.66)	1,607.35 (174.36)	0.57	1,696.65 (199.48)	1,214.47 (91.47)	5.80*
	W4	1,050.55 (50.11)	1,044.69 (116.47)	0.00	1,026.69 (91.14)	916.19 (67.66)	0.99
OO	W2	1,568.77 (72.47)	1,612.81 (84.74)	0.16	1,514.56 (126.23)	1,570.30 (98.73)	0.11
	W3	1,604.76 (91.37)	1,599.36 (105.63)	0.00	1,230.59 (103.18)	1,242.06 (68.99)	0.01
	W4	952.48 (48.45)	985.52 (70.18)	0.16	1,093.33 (116.06)	1,033.32 (78.89)	0.19
OS	W2	1,312.98 (74.49)	1,346.66 (56.70)	0.12	1,292.85 (131.39)	1,359.16 (81.52)	0.19
	W3	1,525.64 (90.58)	1,277.62 (62.69)	4.50*	1,399.29 (137.39)	1,391.58 (96.82)	0.00
	W4	1,361.64 (96.66)	1,540.06 (256.64)	0.51	1,270.11 (208.68)	1,161.45 (76.83)	0.37

Note. TD = children with typical development; SLI = children with specific language impairment.

$^*p < .05$.

impaired processing account and the syntactic deficit account, online and off-line tasks of RC sentence processing were used. Also, in order to examine whether two groups of children showed the proper real-time processing of RC sentences in Korean, the focus was given to critical regions in RC sentences.

In general, the results showed that the TD group and the SLI group processed the SRC sentences and the ORC sentences comparably for the HSM constructions through the online processing task. However, with the HOM construction, different processing patterns were observed between the two groups in processing the SRC and ORC sentences. This was presumably due to the limited morphosyntactic knowledge in the SLI group as compared with the TD group. There were also differences in accuracy with the off-line comprehension task, the TD group performing better than the SLI group both on SRC sentences and on ORC sentences, in both constructions.

Online Sentence Processing

We found no effect of group or RC type in online processing at each word position in the HSM construction; hence, there was no support for any account of SRC/ORC asymmetry for processing. These results are in line with Mansbridge et al. (2016), whose study found no RT differences between SRC and ORC in first-fixation and first-pass durations, measured by eye tracker. Although they found a significant difference between the two types of RC during the go-pass duration, considering the methodological difference of using SPR and eye tracker approaches, the finding of no effect on RC type was similar between the two studies. However, comparing RTs between adjacent words, there was an effect of word position in both RC types, with Word 3 (head noun) taking longer to process than Word 2, and Word 4 more quickly processed than Word 3, in both groups. Given the fact that there was no effect of RC type, it seemed that the general integration cost occurred at the head noun position in both RC types.

Additionally, the general processing pattern looked similar between the correct RT and the incorrect RT in both groups. However, for the SLI group, the correct RT at the head noun was slower than the incorrect RT, which may indicate that the appropriate integration processing was limited at the head noun position in the incorrect RT. In the SLI group, the incorrect RT was faster than the correct RT, across word positions in general for the HSM construction, suggesting inefficient processing.

Table 10. Generalized linear mixed-effects model estimates and *z* values for the off-line sentence comprehension accuracy in HSM sentence.

Variable	Est. (β)	*SE*	*z*	*p*
(Intercept)	−0.415	0.280	−1.482	
Group	0.889	0.266	3.335	.001*
RC type	0.122	0.346	0.354	.723
Group × RC Type	0.417	0.281	1.486	.137

Note. RC = relative clause.

$^*p < .01$.

Table 11. Generalized linear mixed-effects model estimates and *z* values for the off-line sentence comprehension accuracy in HOM sentence.

Variable	Est. (β)	*SE*	*z*	*p*
(Intercept)	−1.000	0.278	−3.602	
Group	1.027	0.340	3.023	.003*
RC type	0.133	0.264	0.505	.614
Group × RC Type	−0.053	0.284	−0.188	.851

Note. RC = relative clause.

$^*p < .01$.

Table 12. Linear mixed-effects model estimates and *t* values for the off-line sentence comprehension response time in HSM sentence.

Variable	Est. (β)	*SE*	*t*	*p*
(Intercept)	9.102	0.088		
Group	–0.111	0.085	–1.301	.197
RC type	–0.175	0.112	–1.558	.126
Group × RC Type	0.084	0.096	0.874	.383

Note. RC = relative clause.

The reason why the effect of RC type did not reach statistical significance may be due to the fact that the two sentence types were not sufficiently different to drive differential processing effects. This is presumably due to the similar sentence structure between the two types—the sentences only differed in the first case marker of each RC sentence, one being accusative and the other being nominative. Based on the TD group's similar RTs at Word 1 and Word 2, in SO type and SS type, the nominative case marker in the first position of the ORC sentences may be considered as the subject of the main sentence. Furthermore, the accusative case marker in the first position for the SRC sentences may not seem odd to children with TD, because of flexible word order in Korean language. This might not drive any differential processing difficulty between the SRC and ORC sentences for children while the sentence unfolds.

The SLI group showed longer RTs at Word 1 compared to Word 2 in the SS type, and they took longer at Word 1 than the TD group in the SO type. However, the reason for their generally longer RTs at the first position in both HSM and HOM constructions is not clear. The similar patterns of real-time performance between the two groups for the HSM construction suggest that the SLI group may process the syntactic structure of RC in the HSM construction comparably to the TD group. However, it should be noted that the predicted patterns of increased RTs at Word 2 were absent, as was the RC effect at Word 3, even in the TD group. It is therefore possible that the HSM construction used in the current study was not syntactically complex enough to fully distinguish the processing difficulty between SRCs and ORCs in children due to the use of simplified and controlled SRC/ORC sentences.

Table 13. Linear mixed-effects model estimates and *t* values for the off-line sentence comprehension response time in HOM sentence.

Variable	Est. (β)	*SE*	*t*	*p*
(intercept)	9.068	0.104	87.420	
Group	0.017	0.119	0.144	.886
RC type	–0.023	0.115	–0.197	.844
Group × RC Type	0.037	0.116	0.317	.751

Note. RC = relative clause.

Unlike findings for the HSM constructions, the RT patterns between the two groups for HOM constructions were noticeably different. The RT pattern in the TD group mostly followed the expected longer RT at critical regions, while the RT pattern in the SLI group did not.

The longer RT at Word 2 in the OO type may suggest a similarity-based interference effect due to the same case markers in the first two NPs. The TD group's RT at Word 2 increased, compared to the RT at Word 1, suggesting that processing interfered in this region. The significant difference in RTs between the OO type and the OS type at Word 2 supports this interpretation for the TD group. However, the SLI group did not seem to be influenced by similarity-based interference, since there was no such effect observed at Word 2, suggesting that the SLI group might be less sensitive to the key morphosyntactic features of RC sentences. Error analyses of RT showed that, overall, participants who were incorrect on a comprehension question in the OO type spent less time at Word 2 than at Word 1, suggesting no interference effect in incorrect sentences supplied for comprehension questions.

Furthermore, the longer RTs at Word 3 (RC verb) in the OO type suggest an experience-based RC surprisal cost. In the TD group, given that the RT at Word 3 was similar to the RT at Word 2, the processing difficulty seemed to continue from Word 2 caused by the similarity-based interference effect. Based on the longer RT at Word 3 than at Word 4, it can be inferred that the experience-based RC surprisal cost took place at Word 3 in the TD group. That is, in the TD group, the structural disambiguation occurred at the RC verb, which contained an adnominal marker. The TD group's faster RT for Word 4 in the OO type was not expected, but they recognized the RC structure. It may be possible that the infrequent double NPs, with the same nominal case markers and the transitive RC verb, provide cues that the object of an RC and a matrix sentence is expected, resulting in a reduced integration cost. On the contrary, the SLI group showed no RT difference between Word 2 and Word 3 in the OO type. Their faster RT at Word 3 in the OO type than in the OS type suggests that experience-based RC processing was not available to the SLI group.

In the TD group, the longer RT at Word 4 in the OS type compared with the OO type seems to suggest that modification and integration may be processed from interpretation. This would be based on the word order–based strategy of the garden path effect, because the level of processing difficulty looked similar to the RT at Word 3, which contained the adnominal marker. In the ambiguous context, the first two NPs in the OS type carried nominative and accusative markers, respectively, potentially misleading the parser to interpret them as the subject and object in a matrix sentence while the sentence unfolds. Thus, when the parser encounters the RC verb, they recognize the RC structure, realizing that the sentence is not a simple sentence following the Korean canonical order. This way, at the head noun, the modification cost via reanalysis and integration is expected to occur.

Likewise, based on the SLI group's longer RT at Word 4 in the OS type than in the OO type, the processing cost seemed to occur by modifying and integrating the misinterpreted structure, misled by the garden path effect. However, the RC effect observed in the SLI group may not suggest the comparable processing mechanism shown in the TD group. If the SLI group could use morphosyntactic cues to interpret RC structure, similar levels of processing difficulty to those shown in the TD group, due to RC recognition, should be observed at Word 3 in the OO type as well. However, the pattern of real-time processing for the OO type seemed to accelerate as the sentence unfolded, suggesting that appropriate real-time processing may not be available in the SLI group. Thus, we speculate the SLI group's significant RC effect at Word 4 (and probably at Word 3) is likely driven by relatively fast processing of Word 4 in OO, not by the modification and integration cost of the garden path effect.

With HOM constructions, the overall RT patterns between the correct RTs and incorrect RTs in the SLI group looked similar. However, there was a significant difference between the correct RTs and incorrect RTs at Word 3 in the HSM construction, with the incorrect RTs taking less time than the correct RTs. This finding suggests that the SLI group may experience greater difficulty in processing RC sentences in HOM construction than in HSM construction, showing no RT increase for any region. The TD group also showed similar patterns between correct RTs and incorrect RTs, except that they took longer at Word 3 (RC verb) in the correct RTs than in the incorrect RTs with the OS type. The faster incorrect RTs at this region may indicate that the RC surprisal cost did not occur, leading the TD group to fail to understand the sentence correctly.

Together, the overall group difference in RTs was not found between children with SLI and children with TD for HSM constructions. On the other hand, different RT patterns were found between the two groups in HOM constructions. Specifically, the TD group seemed to be able to use morphosyntactic knowledge in processing RC sentences in HOM construction. However, the SLI group did not seem to use morphosyntactic knowledge regarding case markings and had difficulty recognizing and building the proper syntactic structure by assigning an appropriate thematic role to each NP while reading RC sentences in HOM construction (van der Lely, 2005).

In addition, some faster RT patterns in the SLI group than in the TD group were observed, not only in the correct RT data for HOM constructions but also in incorrect RT data for both HSM and HOM constructions. The faster RT processing pattern appeared to differ somewhat from the impaired processing account, characteristic of a slower processing mechanism as the cause of SLI in children. It seemed that the relatively faster RT pattern in the SLI group compared to the TD group may indicate poorer or less efficient online syntactic processing, induced by their limited RC syntactic knowledge. These results go against earlier evidence suggesting that real-time processing mechanisms and processing strategies between the two groups may not differ even though children with SLI have lower language abilities (Hestvik et al., 2010; Leonard, 1998).

Off-line Sentence Comprehension

Unlike the online processing task, there was no effect of RC type in the children's performances of the off-line comprehension task, showing similar accuracies for the SRC and ORC sentences, in both HSM and HOM constructions. This result is in line with previous studies, showing no difference in accuracy between SRC and ORC sentences in Korean adult speakers (Kwon et al., 2010; Mansbridge et al., 2016). However, a clear group difference was found in the off-line comprehension task. The TD group was more accurate than the SLI group with the HSM and HOM constructions, suggesting a syntactic problem for the SLI group.

Based on the comparable EF skills in children with SLI and children with TD, the performance of the off-line comprehension task did not seem to be related to reduced cognitive resources (Montgomery, 2000). It could be possible that other language modalities may influence performance on this off-line task, given that children with SLI had significantly lower scores on all subtests in the LSSC. However, the RC sentences used in the current study are syntactically complex sentences in which (morpho)syntactic knowledge is critical in order for a parser to build up the correct semantic–syntactic representation of what they have just read. The materials were also carefully constructed to minimize the lexical–semantic factor, matching and using high-frequency words and the number of words in a sentence. Thus, we suggest that the syntactic modality most likely affects the poorer performance of the comprehension task in the SLI group, compared to the TD group.

However, we do not exclude the influence of other language modality components because, as van der Lely (2005) suggested, it is hard to suggest a deficit in one specific component of language without considering the acquisition of other language components. A future study including a control group for children with SLI, carefully matching another language modality (e.g., matching receptive syntax), may help disentangle this problem in interpreting the data.

One odd finding was that the overall accuracies on the comprehension task seemed low in both groups, although the accuracy of each sentence type for both groups was over the chance level. The only exception was that the TD group had relatively high accuracy rates on the SS type sentences. The lower rate of accuracies might be due to the control of materials to avoid lexical bias. Young children have been reported to depend on various cues, such as semantic cues like animacy and syntactic cues like word order and case marking, in comprehending sentences. The animacy cue is followed, developmentally, by the word order cue and case marking cue (E. Bates et al., 1984; Evans & MacWhinney, 1999). In the current study, using animals for the nouns and minimizing the typical semantic relationship between noun and verb, the semantic cue was limited for comprehending RC sentences. Without the availability of the semantic cue, the experimental sentences were complex sentences, including both canonical and noncanonical word order. This could make understanding the target sentence more difficult for children, resulting in overall lower accuracy rates.

Alternatively, the overall lower accuracies on the comprehension task might have been due to the nature of the task. Children were required to choose one picture out of four, including three foil pictures, corresponding to the target sentence. To complete the job, the children needed to remember the meaning of a target sentence and to match the target sentence to each picture by building the linguistic representation of foil pictures simultaneously. This process might be more taxing, requiring a great cognitive demand, leading to the lower accuracies in the comprehension task (Montgomery, 2000). Nevertheless, cognitive ability did not seem to influence performance on the off-line comprehension task in either group: The general EF abilities were similar between the two groups. In both groups, however, accuracy rates for each sentence type seemed to reflect the difficulty of RC sentences well, depending on the grammatical role in the RC or matrix sentence. This suggests that the stimuli may not have interfered in our observation of the expected RC difficulty in this study. It seemed that the accuracy on the off-line comprehension task seemed to sufficiently discriminate the syntactic difficulty in RC sentences between the SLI group and the TD group.

Conclusions

The RTs measured in real-time processing might not have been sensitive enough to detect the syntactic difficulty in sentence processing when using the HSM construction with the SLI group, compared to the TD group. However, the deviant pattern of RT in the HOM construction in the SLI group compared with the TD group partially supports the syntactic deficit account since the expected increased RTs at critical regions were not observed in the SLI group. These results indicate that the SLI group may be unable to use (morpho)syntactic knowledge to rebuild the sentence structure properly by assigning an appropriate thematic role while unfolding the sentence containing an RC. Furthermore, the SLI group performed poorer on the off-line comprehension task than the TD group, favoring the syntactic deficit account for processing RC sentences in Korean.

The current study has theoretical and clinical implications. Theoretically, our study extends the line of research examining whether the difficulty of RC sentence processing, in children with SLI, is caused by an impaired syntactic system, an impaired processing mechanism, or both. Specifically, ours is the first study examining RC sentence processing using both online and off-line processing tasks, focusing on children with SLI whose native language is Korean, a prenominal language. Clinically, our findings confirmed morphosyntactic difficulties in children with SLI, compared to children with TD, in the off-line RC comprehension task and partially in the online RC processing task, even when relatively easy lexical items were selected as stimuli in the real-time processing task. Although additional research is needed to test other factors that could influence children's performance on these tasks, the findings in the current study show promise for clinical practice.

Case markers are critical for children learning the Korean language and important clinical markers in children with language impairments. They are very short in phonological duration and consist of only one syllable (e.g., /*ga*/ for subject case marker, /*eul*/ for object case marker). Thus, case marking is not very salient in oral or in written format, but it does carry a lot of information about which function is important. Thus, in intervention sessions, speech-language pathologists should emphasize case markers so that children can be aware of them. For example, clinicians can elongate the duration or maximize the loudness of the case marker when they give language input. This kind of activity will help children with language impairments to be aware of case markers and will eventually enhance their ability to process syntactically complex sentences, such as RC sentences in Korean.

This study has some limitations. The RC sentences used for the sentence-processing task were prepared with simpler constructions and easier lexical items than those found in sentences used in real life. The experimental environment and the unnatural materials were different from how RC sentence processing is done in daily life. Especially since the sentence construction was too simple and controlled to render a distinguishable processing difficulty between SRCs and ORCs, the null effect was observed with HSM constructions.

Additionally, we used the SPR approach to measure the RT of each word in a sentence. With SPR, it is impossible to go back to the previous word to recheck the item. The breakdown of a sentence into words and the nature of the SPR method may have hindered our observation of more natural RC processing. A future study would need to use RC sentences featuring more natural lexical items in order to observe more reliable data. Further studies will also need to follow up and to examine whether patterns similar to those observed in this study can be found with more participants and using a different approach to reading, such as an eye-tracking methodology.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2016S1A5B5A01021774, awarded to Jeewon Yoo). The authors would like to thank the children who participated in this study. The authors thank Eun Jung Kong, Ji Sook Park, Margarethe McDonald, and Ilyoup Kwak for helpful comments in analyzing data and Anna Shin and Tyra Shin for their help with proofreading on the earlier version of the article.

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Appendix A

EF Tasks Description

1. Working Memory: In order to measure working memory ability, the backward digit span task and the backward matrix task were administered to participants. In this task, a series of digits were presented auditorily. After listening to the sequence of digits, participants were required to recall the digits in reverse order. The recorded digits were presented with 500-ms intervals between each digit. The span started from two to nine, with each span having two trials. The task was stopped when two trials were incorrect in a span.

The backward matrix task is frequently used to measure the visual working memory capacity. In this task, a 3 × 3 matrix was presented on the screen, with a cell that changed color from white to red one at a time, each lasting 1,000 ms. The location of the red cell was changed randomly so that no same successive red cells were highlighted in a span. Participants had to recall the red cell's location in reverse order by pressing the target cell with a mouse on the computer screen where a white 3 × 3 matrix appeared. Like the backward digit span task, the span started from two to nine, with each span having two trials, and the task was stopped when two trials were incorrect in a span. Two or three practice trials were prepared to ensure that participants understood both working memory tasks. The mean accuracies were obtained for these tasks and used for final analyses.

2. Inhibition: In order to measure inhibition ability, a flanker task was administered to participants. We adopted the flanker task from the National Institutes of Health Toolbox Cognition Battery (www.nihtoolbox.org). The flanker task consisted of three conditions: the congruent condition where both flanker fish and a middle fish faced the same direction in the congruent condition, the incongruent condition where flanker fish faced the opposite direction from the middle fish, and the neutral condition where flanker stimuli were squares. Participants were asked to press a right button (e.g., "/" in the keyboard) if the middle fish faced to the right and to press a left button (e.g., "z" on the keyboard) if the middle fish faced to the left. On this task, the anchor point, located at the center part 20 cm away from the two buttons (e.g., "z" and "/" on the keyboard), was given, and participants were told to put their finger at the anchor point every time after they pressed the buttons. In this task, participants were asked to respond as quickly and accurately as possible. The mean accuracies and RTs were collected for each condition. For analyses, an inhibition index was obtained by subtracting the RT in the congruent condition from the RT in the incongruent condition.

3. Shifting: In order to measure the shifting ability, a DCCS task was administered to participants. We followed the DCCS paradigm obtained from the National Institutes of Health Toolbox Cognition Battery (www.nihtoolbox.org). In the DCCS task, three conditions, including the shape (rabbit and boat), the color (white and brown), and the mixed condition (shape and color), were constructed. In this task, participants were asked to sort test cards according to one dimension (e.g., shape) first and then according to another dimension (e.g., color). In the mixed condition, two conditions (shape and color) were presented mixed. On each condition, participants were reminded of the dimension (shape or color) and were asked to press a right (e.g., "/" in the keyboard) or a left button (e.g., "z" in the keyboard) to choose a correct target picture according to a given dimension. As in the flanker task, the anchor point at the center part 20 cm away from the two buttons (e.g., "z" and "/" in the keyboard) was given, and participants were told to put their fingers at the anchor point after each time they pressed the buttons in this task. Participants were asked to complete each condition as quickly and accurately as possible, and accuracies and each RT of each condition were collected. For analyses, accuracy and RT in the switching trials were used, since this trial was the one that demanded the most attention.

Appendix B

An Example of Frequency of Each Word in Noun Positions for Each Sentence

Word	Frequency	Word	Frequency	Word	Frequency
chicken	106	goat	37	goose	58
cow	171	pig	159	frog	114
rabbit	168	turtle	35	bird	271
deer	66	monkey	54	horse	163
cat	137	dog	375	duck	74
elephant	51	sheep	54	fox	37
Average	116.5		119		119.5

Note. This is one list of the noun positions in the SS type. An example sentence produced in this list was "cat-ACC bite-AND dog-NOM duck-ACC ties up (The dog that bites the cat ties up the duck)."

Appendix C

An Example of Four Pictures for a Subject Relative Clause Sentence in HSM Construction on the Off-Line Comprehension Task: cat-ACC bite-ADN dog-NOM duck-ACC tie up (English: "The dog that bites the cat ties up the duck")