Subject-gap preference in processing of Korean relative clauses: An eye-tracking study*

Miseon Lee
(Hanyang University)

Lee, Miseon. 2009. **Subject-gap preference in processing of Korean relative clauses: An eye-tracking study.** *Korean Journal of Linguistics*, 34-2, 359-373. This paper investigates the comparative processing difficulty of dative and subject relative clauses in Korean, using an eyetracking method. Previous studies of relative clauses have concluded that an object gap is more difficult to process than a subject gap across languages. Two possible explanations for this subject-gap preference are that an object gap is a) structurally more distant from its head or b) linearly more distant from its head than a subject gap. The explanation in (a) predicts that a dative gap should be more difficult to process than a subject gap in Korean while that in (b) predicts the relative ease of a dative gap. The current results of response times and question-answering accuracy confirmed the subject-gap preference: that is, subject gaps were processed faster and more accurately. Eye movement patterns also showed a difference between the two gap types in the amount of active eye movements and fixation durations, indicating that a dative gap is more difficult to access and thus takes more time to process. Thus the current study provides support for the structural distance hypothesis.
(Hanyang University)

Key words: Korean relative clauses, online sentence processing, the structural distance hypothesis, eyetracking method

1. Introduction

Previous studies of relative-clause processing have concluded that subject relative clauses as in (1a) (i.e., relative clauses containing a gap in the subject position) are easier to comprehend than object relative clauses such as (1b) across languages (e.g., de Villiers et al. 1979; Gibson, Desmet, Grodner, Watson & Ko 2005; King & Just 1991; King & Kutas 1995; Lin 2006; Miyamoto & Nakamura 2003; Sheldon 1974; Tavakolian 1978; Traxler, Morris & Seely 2002; Ueno & Garnsey 2008). The

* I thank anonymous reviewers for their helpful comments. This work was supported by the Korea Research Foundation Grant funded by the Korean Government (MOEHRD, Basic Research Promotion Fund) (KRF-2006-332-A00142).

Accessibility Hierarchy, proposed by Keenan & Comrie (1977), shows that this subject-gap preference is universal by describing an implicational hierarchy of relativization (i.e., subject > object > oblique).

(1) a. the man who met Mary
b. the man Mary met

Two contrasting explanations, among others, for the subject-gap preference exist in the relative-clause processing literature: the structural distance hypothesis (O'Grady 1997) and the linear distance hypothesis (e.g., Frazier, Clifton & Randall 1983; Gibson 1998, 2000). Although the two accounts attribute the relative difficulty of relative clauses to the distance between a gap and its filler, they measure the filler-gap distance in a different way: the structural distance hypothesis measures the phrasal distance by counting the number of intervening phrasal structures while the linear distance hypothesis the temporal distance by counting the intervening words.

The structural distance hypothesis, based on the structural difference between gap types, predicts that an object gap is relatively more difficult to process than a subject gap because the structural distance between a gap and its filler increases with an object gap. O'Grady calculates the distance in terms of the number of intervening maximal projections. For example, there are two maximal projections (i.e., S and VP) between the object gap and its filler in object relatives (2b) while there is only one (i.e., S) between the subject gap and its filler in subject relatives (2a). Therefore, the subject gap is structurally closer to the head noun and thus more easily accessed than the object gap.

(2) a. the man [$_{S}$ who __ met Mary]
b. the man [$_{S}$ Mary [$_{VP}$ met __]]

The linear distance hypothesis, on the other hand, focuses on processing resources involving in understanding the filler-gap relation, predicting that the longer the linear distance between a gap and its filler, the greater the working memory and processing load (Gibson 1998, 2000). Frazier et al. (1983) have shown that the linear distance between a filler and its gap in head-initial languages demands substantial working memory to store the filler until encountering a gap and also

a considerable processing load to process the sentence materials in between the two. Thus, the processing difficulty increases with object relative clauses in English (2b), with two intervening words, whereas subject relative clauses (2a) are easier to process because they have a linearly closer gap to the head, with only one word in between.

These two hypotheses successfully explain the subject-gap preference in head-initial languages such as English. However, when it comes to head-final relative clauses as in (3), they make contrasting predictions: given that the subject gap is structurally closer to the head noun but linearly more distant from the head noun in Korean, the structural distance hypothesis predicts subject-gap preference, but the linear distance hypothesis object-gap preference. In order to evaluate the validity of the two contrasting explanations, therefore, it is necessary to see the relative difficulty of relative clauses in head-final languages such as Korean.

(3) a. *Subject relative clause:*
[$_S$ __ Mary-lul manna-n] namca
Mary-ACC meet-REL man[1]
b. *Dative relative clause:*
[$_S$ Mary-ka [$_{VP}$ __ manna-n] namca
Mary-NOM meet-REL man

In fact, previous experimental studies of head-final languages including Japanese and Korean have found that subject relative clauses were read faster than object relative clauses in self-paced reading tasks (Kwon, Polinsky & Kluender 2006; Miyamoto & Nakamura 2003; Ueno & Garnsey 2008). In addition to confirming the crosslinguistic preference for a subject gap, the purposes of the current study are to examine the online processing patterns of Korean relative clauses and thereby to evaluate the validity of the two accounts for relative-clause processing.

2. Experiment

An eyetracking experiment was designed to see the online processing patterns of Korean relative clauses. Two types of relative clauses were

1 ACC = Accusative case; REL = Relativizer; NOM = Nominative case

tested—subject relative clauses (SRs) and dative relative clauses (DRs), as exemplified in (4). A gap is postulated at the first NP marked with a dative case marker in SRs, while in DRs the embedded verb's argument structure will first signal a gap within a relative clause. In all stimulus sentences, the head noun modified by a relative clause occurred in the subject position of the matrix clause.

(4) a. *Subject relative clause:*
[ecey $\_\__i$ Mary-eykey kkoch-ul cenha-n] mescin John$_i$-i ...
Yesterday Mary-DAT flower-ACC hand-REL handsome John-NOM
'Handsome John who handed a flower to Mary yesterday...'

b. *Dative relative clause:*
[ecey John-i $\_\__i$ kkoch-ul cenha-n] yeyppun Mary$_i$-ka ...
Yesterday John-NOM flower-ACC hand-REL pretty Mary-NOM
'Pretty Mary who John handed a flower yesterday ...'

To create a dative gap, *give*-type verbs were used within the relative clauses. The verbs can take three arguments: an agent, a goal, and a theme, marked with a nominative, a dative, and an accusative case marker, respectively. Given that previous conclusions on filler-gap processing are mostly based on the subject—object gap asymmetry (e.g., King & Just, 1991; Gibson, 1998; Traxler et al., 2002; Lin, 2006; Kwon et al., 2006), we can extend the findings of previous studies by investigating another gap type. Furthermore, the distance between a gap and a head noun is more salient both structurally and linearly with a dative gap than with an object gap.

2.1 Method

2.1.1 Participants

Forty-two native Korean speakers participated in this experiment. They were college students and had normal or corrected-to-normal vision and hearing. All participants were paid for participation.

2.1.2 Materials

Sixty-four sets of test items were prepared, including 32 sets of targets (16 SRs and 16 DRs) and 32 sets of unrelated distractors. Each set

consisted of a context story, a picture panel, and a comprehension question. The target relative clauses were presented in the form of yes/no comprehension questions as in (5) in order to confirm whether the participants paid attention to the ongoing test as well as to examine how they processed relative clauses.

(5) a. *Subject relative clause:*
[ecey $\_\__i$ Mary-eykey kkoch-ul cenha-n] mescin John$_i$-i
kipwun-i coh-ass-eyo?
Yesterday Mary-DAT flower-ACC hand-REL handsome John-NOM
feeling-NOM be.good-PAST-INTR
'Did handsome John who handed a flower to Mary yesterday feel good?'

b. *Dative relative clause:*
[ecey John-i $\_\__i$ kkoch-ul cenha-n] yeyppun Mary$_i$-ka
kipwun-i coh-ass-eyo?
Yesterday John-NOM flower-ACC hand-REL pretty Mary-NOM
feeling-NOM be.good-PAST-INTR
'Did pretty Mary who John handed a flower yesterday feel good?'

A picture panel presented on the computer monitor consisted of four colored pictures of animated entities (people or animals) and other objects: one target picture (semantically corresponding to the head noun), two related pictures, and one unrelated picture. The position of the target picture was randomized so that it did not appear on the same position on the monitor in three consecutive test items.

2.1.3 Procedure

The experiment was carried individually in an eyetracking laboratory. The head-mounted eyetracker (EyeLink II, SR Research) was fully calibrated before the experiment began and the calibration was checked regularly during the experiment. Pupil location was sampled at a rate of 250 Hz.

A 'visual-world paradigm while listening' design was employed to collect eye movement data. Participants viewed a picture panel on the computer monitor while hearing a pre-recorded context story involving the entities in the picture panel. Participants were then asked to listen to a comprehension question containing either a SR or a DR while viewing the same pictures on the monitor. Also, they were instructed

to immediately answer the comprehension question by pressing a button labeled 'yes' or 'no' on a button box. There were four practice trials before the main experimental session.

2.1.4 Analysis

Participants' eye movements to the target pictures, fixation durations, and responses to comprehension questions were automatically recorded into the computer. Fixation duration is the sum of all fixations on a picture before the eyes move out of the picture to another picture (Rayner 1998). This measure is generally known as a measure of initial sentence processing and of the cognitive load involved in processing a sentence.

Participants' eye movements and fixation durations were analyzed for each of the eight segments exemplified in Table 1 below.

Table 1. Analysis of eight segments in SRs and DRs

Gap type	S1	S2	S3	S4	S5	S6	S7	S8
SR	yesterday __	Mary	-DAT	flower	-ACC	hand-REL	handsome	John
DR	yesterday	John	-NOM __	flower	-ACC	hand-REL	pretty	Mary

A relative clause began with an adverb such as 'yesterday' at Segment 1. In SRs, a subject gap is postulated to exist at Segment 1. Then the first NP was presented at Segment 2, followed by a case marker at Segment 3 −a dative case marker in SRs and a nominative case marker in DRs. Segment 3 is postulated to include a dative gap in DRs. Then the second NP and an accusative case marker were presented at Segments 4 and 5, respectively, in both SRs and DRs. Segment 6 was the position for the embedded verb, which was combined with a relativizer -*(nu)n* and thus explicitly marked the relative clause for the first time. At Segment 7, an adjective modifying the head noun (e.g., *pretty, handsome*) was presented. Finally, the head noun (i.e., the filler) appeared at Segment 8.

2.1.5 Predictions

As discussed earlier, the two explanations (i.e., the structural distance hypothesis and the linear distance hypothesis) predict the same subject-gap preference in head-initial languages such as English. However, they make contrasting predictions for Korean relative clauses: the structural distance hypothesis predicts the preference for a subject gap while the linear distance hypothesis the preference for a dative gap.

Participants' eye movements and fixation durations may show how SRs and DRs are processed over time, and thereby provide support for either the structural or the linear distance hypothesis. Given that eye movements reflect cognitive processing at the moment (Liversedge, Paterson, & Pickering 1998; Rayner 1998), if a gap is recognized and processed, eye movements to the target picture will be active prior to hearing the head noun, reflecting the cognitive activity to fill the gap with a filler. Also a longer duration of gaze fixation at a certain point will reflect more complex cognitive activities than at other points. Thus, it is possible to tell whether the structural distance or the linear distance between a gap and its filler determines the relative processing difficulty by examining the patterns and timing of eye movements.

2.2 Results

2.2.1 Question-answering accuracy and response times

As shown in Table 2, participants correctly answered 98% of the comprehension questions containing a SR, and 93% of those containing a DR. This difference in accuracy between SRs and DRs was significant (F = 4.228, p <. 05), indicating that comprehension questions containing a DR was more difficult even for adult native speakers of Korean to answer than those with a SR.

The gap type also made a significant influence on the duration of processing relative clauses: mean response times were significantly shorter for the comprehension questions containing a SR than for those containing a DR (F = 5.045, p < .05), suggesting that the gap type may allocate different processing load.

Table 2. Mean response times to comprehension questions

	Types of relative clauses			
	SRs		DRs	
Response	Correct	Incorrect	Correct	Incorrect
Accuracy	98%	2%	93%	7%
Mean reaction time (ms)	705.4	1025.25	801.33	1667.33

2.2.2 Eye movements

Participants' eye movements to the target picture (i.e., the picture semantically corresponding to the head noun) were measured in terms of the proportion of saccadic eye movements while listening to the relative clauses contained in comprehension questions. The eye movements were analyzed only for correctly responded items. To test the statistical significance of eye movement patterns, analyses of variances (ANOVAs) were performed on participant and item means at each segment.

Figure 1 shows the mean proportion of eye movements to the target picture at each of the eight segments while listening to a relative clause.

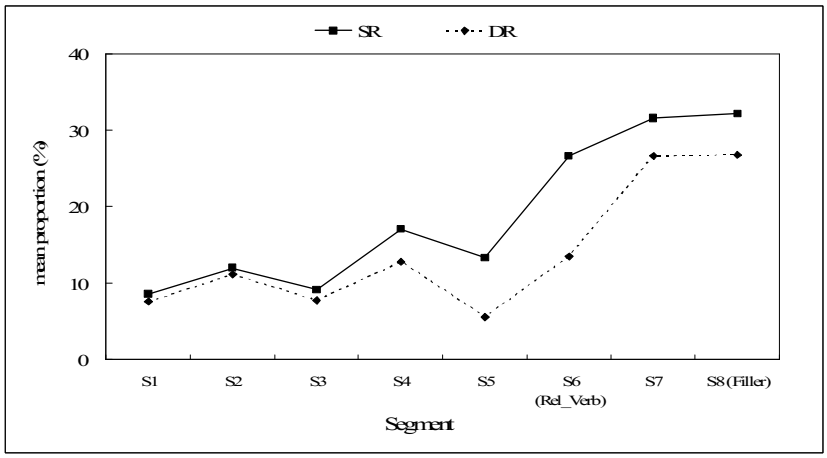

Figure 1. Eye movements to the target picture in SRs and DRs

As shown in Figure 1, the general patterns of eye movements to the target picture are similar in SRs and DRs. While listening to a relative

clause, participants hardly looked at the target picture before they heard the second NP at S4. The participants only launched to look at the target picture when they heard the second NP (S4). Then their inspections to the target picture significantly increased at S6 when hearing the relativizer combined with an embedded verb (for SRs: F_1 = 9.972, p = .003; F_2 = 13.727, p = .002; for DRs: F_1 = 6.787, p = .013; F_2 = 5.257, p = .037). They continued to increase shortly after the relativizer (S7) until the head noun (S8).

However, the effect of gap type was significant (F_1 = 6.399, p = .015; F_2 = 4.780, p = .045), indicating that the eye movements varied depending on the type of relative clauses. In particular, the amount of active eye movements differed between SRs and DRs. A post-hoc test confirmed that the proportion of eye movements to the target picture was significantly larger in SRs than in DRs at S5 (F_1 = 5.930, p = .019; F_2 = 6.298, p = .024) and S6 (F_1 = 7.182, p = .011; F_2 = 11.506, p = .004).

The effect of segment was also significant in each type of relative clauses (F_1 = 21.127, p = .000; F_2 = 16.173, p = .000). In particular, the difference became significant from the accusative case marker affixed to the second NP (S5): for SRs, participants' looks to the target picture increased from the second NP (S4) until the head noun (S8). On the other hand, for DRs, they significantly decreased during the accusative case marker at S5 (F_1 = 7.785, p = .008; F_2 = 4.685, p = .047). They then increased significantly during the embedded verb affixed with a relativizer at S6 (F_1 = 6.787, p = .013; F_2 = 5.257, p = .037) and again during the head-modifying adjective at S7 (F_1 = 14.829, p = .000; F_2 = 17.258, p = .001).

2.2.3 Fixation durations

Table 3 shows the fixation duration on each of three arguments of the SRs and DRs: i.e., two embedded NPs (S2+S3, S4+S5) and a head noun (S8). In both types of relative clauses, the fixation durations were different among the three arguments; however, the difference was significant only at the head noun (S8), as compared to others in a relative clause (for SRs: F_1 = 18.147, p = .000; F_2 = 6.807, p = .004; for DRs: F_1 = 15.469, p = .000; F_2 = 6.131, p = .015). The longest duration of the fixation during the head noun (S8) suggests that a certain kind of processing was performed at this point.

Table 3. Fixation durations (ms.) on three arguments of SRs and DRs

	S2+S3	S4+S5	S8
Gap type	NP-Dat/Nom	NP-Acc	Head N.
SR	406.10	337.14	538.69
DR	352.33	430.91	568.52

3. Discussion

This study investigated the comparative processing difficulty of subject relative clauses and dative relative clauses in Korean. The response time and accuracy data show that SRs were processed significantly faster and more accurately than DRs. This result confirms the previous crosslinguistic findings that SRs are the easiest to process, as compared to other types of relative clauses. Given that the linear distance between a gap and its filler is longer in SRs than in DRs in Korean, the current results are not explained by the linear distance hypothesis, which predicts the relative difficulty of SRs than DRs in Korean. On the other hand, the results support the structural distance hypothesis of relative-clause processing (O'Grady 1997) because the structural distance between a gap and its filler is still longer in DRs than in SRs. The short structural distance allows the syntactic parser to form and resolve the gap-filler dependency faster and more easily.

The asymmetry observed between SRs and DRs is also evident in the eye movement patterns over time. In Korean, SRs and DRs are first distinguished at the case marker affixed to the first embedded NP. The results evince that this case information contained within a relative clause influenced the successive processing of a sentence. Recall that in SRs the first NP is affixed with a dative case marker whereas it is marked with a nominative case marker in DRs. Thus only the non-canonical case marker on the first NP in SRs can predict a missing nominative argument, whereas the nominative case marker affixed to the first NP in DRs makes no such prediction. Yet since Korean sentences frequently drop or scramble an argument, the first NP marked with a non-canonical dative case marker does not immediately induce eye movements to the target picture. The parser may consider the missing argument is dropped or appears somewhere later, rather than predict a relative-clause gap.

However, by the point that the parser encounters the accusative case marker affixed to the second embedded NP in SRs, it becomes clear to the parser that the sequence of a dative NP and an accusative NP is missing a nominative NP as shown in (6a). Then the parser looks at the target picture, searching for a filler. In DRs, on the other hand, the surface arrangement of two embedded NPs (i.e., a nominative and an accusative) conforms to the canonical word order of Korean (SOV), as shown in (6b). Therefore, there is little possibility that the parser predicts an additional argument at S5 of DRs; rather, it is likely to anticipate a verb. The decrease of eye movements to the target picture during the accusative case marker (R5) in DRs reflects this initial parsing (as SOV).

(6) a. *Subject relative clause:*
John-eykey ttalki-lul …
John-DAT strawberries-ACC …
b. *Dative relative clause:*
John-i ttalki-lul …
John-NOM strawberries-ACC …

In both SRs and DRs, the embedded verb follows the accusative NP and explicitly marks the relative clause by combining with a relativizer *-(nu)n*. As reported earlier, the eye movements to the target picture meaningfully increased during this embedded verb (S6), as compared to preceding segments, in both types of relatives. This result may reflect the possibility that the parser identifies a relative clause and its gap. Yet the proportion of eye movements increased more in SRs than in DRs. This difference can be due to the predictions that the parser makes about a potential gap prior to the embedded verb: that is, the parser predicts a gap based on the case of preceding NPs in SRs while it does not for DRs.[2]

In SRs, the identification of the existence of a gap may have the parser start to search for a filler at an earlier point, even before hearing the embedded verb. On the other hand, at the same point of the accusative case marker in DRs, the parser has no reason to predict a gap, and thus

2 In Korean, the potential gap is temporarily ambiguous at this point, as either a constituent of a relative clause, a dropped argument, or a scrambled argument.

when encountering an embedded verb affixed with a relativizer, it should reanalyze the initial parsing (as SO..) so as to include a dative gap. This is because the embedded verb, which is a 3-place verb, requires three arguments and the relativizer signals an existence of a gap. The result that the eye movements to the target picture increased much less during the embedded verb in DRs than in SRs shows that the parser reanalyzed the initial parsing and thus took more time to identify a dative gap and then to search for its filler.

Participants' looks to the target picture were the most active after the embedded verb, at the adjective modifying the head noun (S7) and the head noun (S8) in both SRs and DRs. The active eye movements at S7 reflects the parser's anticipation of a head noun on hearing the relativizer (S6) and thus identifying a relative clause. In particular, given that the adjective was presented prior to the head noun, the increased eye movements could be due to a spillover effect from the immediately preceding syntactic processing during the embedded verb. In DRs, the parser can predict a gap only at the embedded verb, and thus it should reanalyze the argument structure of the verb at S6. As soon as the parser identifies a dative gap and reanalyzes the argument structure of an embedded verb, it begins to look for the filler actively, which resulted in the larger increase of eye movements at S7, as compared to that in SRs.

The gaze fixation on the target picture was the longest during the head noun at S8. These results, along with the eye movement patterns, evince that the parser forms and resolves the gap-filler dependency on encountering the head noun at S8. Although a gap is identified and its filler is predicted during the embedded verb, the syntactic relation between the two is formed and processed only when encountering the head noun. That is, the parser starts to retrieve a gap on identifying a filler. Therefore, if the gap is located farther from the filler, then the gap retrieval process will take longer. Accordingly, the current finding that the response time and fixation duration during the head noun were longer in DRs than in SRs is consistent with the structural distance hypothesis.

In summary, the significant increase of eye movements to the target picture during the embedded verb (S6) and the head-modifying adjective (S7) prior to the head noun indicates that a relative clause and its gap are expli citly identified during the embedded verb. The longest

fixation duration on the target picture during the head noun (S8) suggests that the gap-filler dependency is processed and the semantic interpretation is achieved at the point. In resolving the gap-filler dependency, a filler needs to retrieve its gap. Thus since a dative gap is more deeply embedded and thus structurally more distant from its filler than a subject gap, a dative gap takes more time and difficulty to retrieve than a subject gap. These overall results provide support for the structural distance hypothesis.

4. Conclusion

To conclude, our eyetracking results show that DRs are more difficult to process than SRs in Korean, as reported in other languages. Two contrasting accounts have been suggested for the crosslingusitic preference of a subject gap in comprehension: the structural distance hypothesis which is based on the structural differences between the two types of gap and the linear distance hypothesis which turns to the number of intervening words between a gap and its filler. They both correctly explain the subject-gap preference in head-initial languages such as English where a filler precedes its gap. However, the current data from Korean, where a filler follows its gap, are consistent only with the predictions of the structural distance hypothesis. Furthermore, they establish that the structural distance hypothesis is a universal constraint on gap-filler processing.

References

de Villiers, J. G., Tager-Flusberg, H. B., Hakuta, K. & Cohen, M. 1979. Children's comprehension of relative clauses. *Journal of Psycholinguistic Research* 8, 499-518.

Frazier, L., Clifton, C. & Randall, J. 1983. Filling gaps: Decision principles and structure in sentence comprehension. *Cognition* 13, 187-222.

Gibson, E. 1998. Linguistic complexity: locality of syntactic dependencies. *Cognition* 68, 1-76.

Gibson, E. 2000. The dependency locality theory: A distance-based theory of linguistic complexity. In A. Marantz, Y. Miyashita, & W. O'Neil (eds.), *Image, Language, Brain: Papers from the First Mind Articulation Project symposium,* 95-126. Cambridge: MIT Press.

Gibson, E., Desmet, T., Grodner, D., Watson, D. & Ko, K. 2005. Reading relatives clauses in English. *Cognitive Linguistics* 16, 313-353.

Keenan, E. L. & Comrie, B. 1977. Noun phrase accessibility and Universal Grammar. *Linguistic Inquiry* 8, 63-99.

King, J., & Just, M. 1991. Individual differences in syntactic processing: The role of working memory. *Journal of Memory and Language* 30, 580-602.

King, J. & Kutas, M. 1995. Who did what and when? Using word- and cause-level ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience* 7, 376-395.

Kwon, N., Polinsky, M. & Kluender, R. 2006. Last resort gap strategy in processing long-distance dependencies. Paper presented at The 19th Annual CUNY Conference on Human Sentence Processing, CUNY Graduate Center, New York, NY.

Lin, C. 2006. *Grammar and Parsing: A Typological Investigation of Relative-clause Processing*. Unpublished Ph. D. Dissertation, The University of Arizona, Tucson.

Liversedge, S. P., Paterson, K. B., & Pickering, M. J. 1998. Eye movements and measures of reading time. In G. Underwood (ed.), *Eye Guidance in Reading and Scene Perception*, 55-75. New York: Elsevier.

Miyamoto, E. & Nakamura, M. 2003. Subject/object asymmetries in the processing of relative clauses in Japanese. *Proceedings of the West Coast Conference on Formal Linguistics* 22, 342-355.

O'Grady, W. 1997. *Syntactic Development*. Chicago: University of Chicago Press.

Rayner, K. 1998. Eye Movements in reading and information processing: 20 years of research. *Psychological Bulletin* 124, 372-422.

Rayner, K., McConkie, G. W., & Ehrlich, S. F. 1978. Eye movements and integrating information across fixation. *Journal of Experimental Psychology: Human Perception and Performance* 4, 529-544.

Sheldon, A. 1974. The role of parallel function in the acquisition of relative clause in English. *Journal of Verbal Learning and Verbal Behavior* 13, 272-81.

Tavakolian, S. 1978. The conjoined-clause analysis of relative clauses and other structures. In H. Goodluck & L. Solan (eds.), *The Structure and Development of Child Language*, 37-83. Amherst: University of Massachusetts, Linguistics Department, GLSA Publication.

Traxler, M., Morris, R. & Seely, R. 2002. Processing subject and object relative clauses: Evidence from eye movements. *Journal of Memory and Language* 47, 69-90.

Ueno, M. & Garnsey, S. M. 2008. An ERP study of the processing of subject and object relative clauses in Japanese. *Language and Cognitive Processes* 23, 646-688.

[133-791] Department of English Language and Literature, Hanyang University
17 Haengdang-dong, Seongdong-gu, Seoul, Korea
Email: mlee@hanyang.ac.kr

Received: May 1, 2009
Revised: June 14, 2009
Accepted: June 22, 2009