

안구운동 추적을 통한 한국어 중의성 해소과정 연구*

Resolving Grammatical Marking Ambiguities of Korean: An Eye-tracking Study

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요 약 한국어의 문법적 표지 중의성 해소 과정과, 한국어의 형태론적 정보 처리과정에 관한 길-혼동 모형과 제약-기반 모형의 예측을 비교 검토하기 위해 안구운동 추적 연구를 수행하였다. 최소부착원리에 따라 구문분석될 수 있는 복합 명사구 구조와, 첫 명사에 주격조사 (-가/이), 한정사(-만), 및 주제표지(-는/은)가 부착되는 삽입 관계절 구조를 비교하였다. 실험 결과, 한국어의 표지 중의성이 최소 부착의 원리에 따라 해소됨을 확인할 수 있었고, 주제표지는 재분석 과정에 영향을 끼침을 알 수 있었다. 안구 고정 시간의 양상은 길-혼동 모형과 더 일치했으며, 제약-기반 설명과는 일치하지 않았다. 추후 연구를 위한 제안을 논의하였다.

주제어 문장 이해, 구문분석, 주제표지, 재분석

Abstract An eye-tracking experiment was conducted to examine resolving processes of grammatical marking ambiguities of Korean, and to evaluate predictions from the garden-path model and the constraint-based models on the processing of Korean morphological information. The complex NP clause structure that can be parsed according to the minimal attachment principle was compared to the embedded relative clause structures that have one of the nominative marker (-ka), the delimiter (-man, which roughly corresponds to the English word 'only'), or the topic marker (-nun) on the first NPs. The results clearly showed that Korean marking ambiguities are resolved by the minimal attachment principle, and the topic marker affects reparsing procedures. The pattern of eye fixation times was more compatible with the garden-path model, and was not consistent with the predictions of the constraint-based accounts. Suggestions for further studies were made.

Keywords sentence comprehension, parsing, topic marker, reanalysis

One of the most important issues in the study of language processing concerns the universality of sentence processing strategies across different languages (e.g., Hillert, 1998; De Vincenzi, 2000; De Vincenzi & Lombardo, 2000). As all researchers agree, if the goal of psycholinguistics is to study the human sentence processor and not the sentence processing mechanisms of a specific language, the test of universality is not an option but the necessary condition for evaluating various models of sentence processing.

A language like Korean constitutes a particularly valuable contrast with a language like English, because the languages differ morphologically and structurally in ways that profoundly affect the flow of information available as a sentence is heard or read. Korean also provides theoretically challenging problems for sentence parsing models (see Clifton, 2000) including the garden-path model (Frazier, 1979; Frazier, 1990; Frazier & Clifton, 1996; Frazier & Rayner, 1982;) and constraint-based models (MacDonald, Pearlmuter, & Seidenberg, 1994; Spivey-Knowlton & Sedivy, 1995; Spivey-Knowlton, Trueswell, & Tanenhaus, 1993).

Korean is headfinal, left branching, has subject-object-verb word order, permits scrambling, and allows phonological null arguments and adjuncts. Typologically, Korean is classified as an agglutinative language with a rich morphology (Suh, 1994).

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Thus, some grammatical functions represented structurally in English are actually represented by way of case markers. Other grammatical functions represented syntactically in English are represented by a change in verbal morphology in Korean. Passive, causative, and mood marking are such instances. Furthermore, the morphological particles not only have various syntactic functions, but also have complex semantic and pragmatic functions in discourse. For example, delimitative particles (delimiters), which are enclitic to the NP like case markers and postpositions, do not specify the grammatical role of the NPs. Rather, they carry semantic implications necessary for the interpretation of the NP or the sentence. Therefore, the first question is what are the role of these morphological elements in sentence parsing. Many psycholinguists suggest that, in languages such as Korean, Japanese, and German, the information of particles attached to NPs and verbal markings might be an important source for generating a hypothesis about syntactic structure (Carlson & Tanenhaus, 1988; Suh, 1994; Weinberg, 1993). There is some evidence from Korean supporting this view (e.g., Kim, 1999). However, morphological information is not always completely unambiguous, rather it is one of the major sources of structural ambiguities in Korean. These ambiguities will be called “*grammatical marking ambiguities*.”

The second question is more theoretical. If morphological information has any effects on the initial parsing or reparsing procedures, which theoretical frameworks or parsing models are better for characterizing the effects? There are different possibilities about when morphological information is employed, depending on whether initial parsing decisions are restricted or unrestricted with respect to available information (Pickering, 1999; Traxler & Pickering, 1996). Unrestricted accounts like the constraint-based models propose that all potentially relevant sources of information, including morphological information, can be brought to bear on parsing decisions immediately (MacDonald et al., 1994; Spivey-Knowlton et al., 1993). However, restricted accounts of parsing propose that there is some stage during which the parser ignores some potentially relevant sources of information. For example, in the garden-path model, the parser makes initial attachment decisions by applying the principles of minimal attachment and late closure, which are defined in terms of major category information. We will discuss how these two accounts could be applied to the grammatical marking ambiguities of Korean sentences in more detail below.

Minimally attach anyway?

The first question of this study is on the minimal attachment processes of Korean sentences that have local ambiguities. For example:

- (1) Bob-ka(-i)¹⁾ Mary-lul manna-n ...
 -Nom -Acc met-Rel or Comp
 (Bob met Mary ... 밥이 메리를 만난...)
- (2) a. Bob-ka(-i) Mary-lul manna-n Jack-lul ttaraessta.
 -Nom -Acc met-Rel -Acc hit-Ind
 (Bob hit Jack who met Mary. 밥이 메리를 만난 잭을 때렸다)
- b. Bob-ka(-i) Mary-lul manna-n sagun-i allyeicssta.
 -Nom -Acc met-Comp fact-Nom was known-Ind
 (The event that Bob met Mary was known. 밥이 메리를 만난 사건이 알려졌다)

The string N-N-V in (1) is ambiguous, i.e., the second noun and the verb can constitute an embedded relative clause like (2a), or it can be parsed as two arguments of the verb and constitute a complex noun phrase like (2b). It depends on the disambiguating head noun that follows the verb. Thinking of the left-to-right parsing of (1), the first analysis can be called “*separate clause analysis*” and the second analysis can be called “*co-argument analysis*.” The co-argument analysis is simpler than that of the separate clause analysis in terms of the number of nodes postulated at “Mary.” Hence, the garden-path model with the minimal attachment principle predicts that the first three words will be parsed as a single clause. Is there any evidence for minimal attachment in this case? Frazier (1987) reported that constituent structure processes of Dutch and English are identical, despite the presence of head-final phrases in Dutch (see also Bader & Lasser, 1994 for German). There is some intuition data that showed preference for the co-argument analysis in Korean and Japanese (Suh, 1994 for Korean; Inoue & Fodor, 1995 for Japanese).

One thing we have to consider for sentence (1) is the fact that the verb contains a *clause-ending marker* (CEM) (i.e., suffix *-n*) that is ambiguous. It is a good example of the grammatical marking ambiguity. In a non-root clause of

¹⁾ Nom: Nominative, Acc: Accusative, Rel: Relative clause marker, Comp: Complementizer, Ind: Indicative mod maker

Korean, the final position is occupied by the clause-ending marker, which signals the grammatical role of the non-root clause. That is, embedded verbs are morphologically marked differently from root verbs. Therefore, when the third word (i.e., *man-na-n*) is received, it becomes clear that there is at least one degree of embedding, since it contains suffix '-n,' which functions either as a relative clause marker or as a complementizer heading a complex NP clause (Suh, 1994). Then, is this morphological information used in initial parsing process? How do the major parsing models such as the constraint-based accounts and the garden-path model incorporate such morphological driven processes?

The garden-path model leaves it open whether the morphological information would be used during initial processing. Thus, first, we will consider only a strong version of the garden-path model. According to the model, the parser does not use this morphological information, because initial attachment decisions are made by the principle of minimal attachment, which is defined in terms of major category information. Therefore, we can assume the co-argument analysis will be performed on the word string (1). Alternatively, we can assume the parser might use the information of the clause-ending marker to project a functional node (e.g., IP or CP) of the whole clause. However, the suffix (-n) itself is ambiguous, and other information about whether the suffix is a relative clause maker or a complementizer is not yet available. Thus, there may be no information requiring structure beyond the simple clause structure corresponding to the co-arguments analysis.

In contrast, the constraint-based accounts assume all potentially relevant sources of information, including the information of the clause-ending marker, can be brought to bear on parsing decisions immediately. Therefore, according to such accounts, the string (1) should be difficult because morphological information supports two syntactic analyses (i.e., the co-argument analysis and the separate clause analysis) and competition between analyses will proceed for a time. There is an experimental finding that might support this inference. Using a self-paced word-by-word reading task, Kim (1999) found significant reading time differences between verbs that have the ambiguous marker -n and the same verbs that have the coordinate conjunction marker -ko. The coordinative marker is a strong cue for the co-argument analysis because the marker is usually used only when clausal

units are connected (Suh, 1994), but the marker -n is ambiguous between the two possible structures. This suggests that more than one syntactic analysis might be performed in the string like (1) and the competition between the two structures would result in the slow reading times. There are not any Korean data that show whether the two syntactic analyses are equally activated, and if there is any preference for one structural analysis in (1). However, the assumption that both structures are activated may be reasonable because both structures are frequently used in Korean.

The predictions from the two models can be verified by examining a disambiguating phrase. The fourth word provides information about the correct sentence structure. In (2a) the head noun (*Jack-ul*) must be an object in the matrix clause and it also must be co-indexed with a subject trace in the relative clause sentence. In (2b) the first three words as a whole must modify the head noun (*sagun-i*) to construct a complex NP clause. As discussed above, the garden-path model predicts a co-argument analysis in (1). Therefore, it expects that processing difficulties will not be observed in (2b), but some processing difficulties must be observed in (2a) because of reanalysis. However, the constraint-based accounts permit parallel activation of and competition between the two analyses. Therefore, one of these structural analysis can be adopted easily both in (2a) and (2b). That is, the models predict no processing difference at the head noun in (2a) and (2b). In summary, the predictions from the garden-path model and the constraint-based accounts were tested by examining the resolution processes of Korean verbal marking ambiguities.

Effects of delimiters: initial parsing or reparsing?

Case particles and postpositions, which are attached to the nominal, signal grammatical roles of NPs in a Korean sentence. Delimiters, which are also attached to the nominal, do not specify the grammatical role of NPs unlike postpositions or case particles. Rather, they provide semantic or pragmatic implications necessary for the interpretation of the NPs or the sentence. They are another example of the grammatical marking ambiguity of Korean. In Korean, we can manipulate a sentence syntactically or semantically just by changing a case particle or a delimiter of NPs without changing the linear order of the sentence. Hence, this property

of Korean provides an interesting arena within which to test various models that predict an absence or presence of interaction effects of various sources of information on sentence processing.

Recently, Kim (1999) reported effects of a delimiter or a topic marker '-*nun*' on Korean sentence parsing. He compared the example sentences like (2a), repeated here as (3), with examples like (4). The two sentences are exactly the same except for the markers attached to the first NPs.

- (3) Bob-ka(-i) Mary-lul manna-n Jack-lul ttaraessta.
 -Nom -Acc met-Rel -Acc hit-Ind
 (Bob hit Jack who met Mary. 밥이 메리를 만난 잭을 때렸다.)
- (4) Bob-nun Mary-lul manna-n Jack-lul ttaraessta.
 -Top -Acc met-Rel -Acc hit-Ind
 (Bob hit Jack who met Mary. 밥은 메리를 만난 잭을 때렸다.)

Using a self-paced word-by-word reading task, Kim (1999) found no difference in reading times between the two conditions until the third word (i.e., the ambiguous region), and found significantly shorter reading times at the fourth word (i.e., the disambiguation location) in (4) than that in (3). He interpreted the effects as indicating that reparsing of the topic marked structure was facilitated. Nevertheless, it is still possible that the topic marker could affect initial parsing procedures in addition to reparsing procedures. If we use a more sensitive measure like eye tracking, we could find the initial parsing effects of the topic marker. Furthermore, the conjecture that the topic marker could affect the initial parsing routine is consistent with the constraint-based accounts.

In Korean, there is a constraint that a topicalized element cannot be used in an embedded relative clause and must be an argument of the matrix clause (c.f., Lee, 1979, for some limited exceptions). Hong (1985), by examining the frequency of the use of the subject marker in written and spoken data, found that the subject of the main clause most frequently appears with the topic marker '-*nun*' and the subject of the subordinate and relative clause most frequently appears with the nominative marker '-*ka*.' So, we can infer the topic marked NPs or sentences might be biased for constructing a main clause structure. As discussed above, the constraint-based accounts predict that two possible syntactic analyses will be activated and compete with each other until the ambiguous third word in (3). What will happen in (4)? In

(4) two syntactic analyses may be activated too in spite of the presence of the topic marker, because both analyses are syntactically possible and correct. However, the topic marker provides extra evidence for the separate clause analysis (i.e. the topic marked NP is not the subject of the embedded clause, but the main clause). It must have a stronger activation level than the co-argument analysis. As a result, there will be significant reduction of competition (or ambiguity) in the topic marked structure compared to the nominative marked structure. In summary, the constraint-based accounts predict shorter reading times in (4) than in (3) at the ambiguous region, and the same prediction will be applied to reading times of the fourth disambiguation word.

In contrast, the garden-path model predicts no reading time differences between the two conditions until the third word, because the parser will compute the simplest analysis (i.e., the co-argument analysis) in all cases. However, information about the topic marker could be used in reparsing processes. The effects of the topic marker on reparsing processes could be explained differently depending on the different reparsing models. The reparsing models and their explanations for the effects of the topic marker will be discussed in a later section.

Another interesting feature of the topic marker is its grammatical marking ambiguity or syntactic function ambiguity (Meng & Bader, 2000). The topic marked NPs can be either a nominative (subject) or an accusative (object). This case ambiguity cannot be explained solely in terms of mechanisms responsible for the computation of phrase-structure. Much German sentence processing research (e.g., Bader, 2000; Schlesewsky, Fanselow, Kliegl, & Krenms, 2000) has shown that the parser does not seem to wait until it encounters the disambiguating verb when making decisions about case assignment. Instead, the decisions about case assignment seem to be made immediately when encountering NPs in need of case. So, is there any default assignment or preference for the topic marker '-*nun*'? Suh (1994) reported that the topic marker attached at the first NP of a sentence seems to be preferred as a nominative case. Do other delimiters with the same ambiguities also have a default assignment?

In order to examine the presence of the syntactic function ambiguity of the topic marker and to compare its possible effects to other delimiters, the following example sentence was included in this study. The difference between (4) and (5) is the delimiter attached in the first NP. The question is

whether the delimiter ‘-man’ also has a default nominative preference. The ‘-man’ roughly corresponds to the English word ‘only.’

(5) Bob-man Mary-lul manna-n Jack-lul ttaraessta.
 -Del (only) -Acc met-CEM -Acc hit-Ind
 (Only Bob hit Jack who met Mary. 밥만 매리를 만난 잭을 때렸다.)

In summary, an eye-tracking experiment was performed in order to examine the effects of the various Korean particles and verbal inflections on sentence parsing, and to test and contrast the predictions from the garden-path model and the constraint-based accounts.

Method

Participants. Sixteen undergraduates from Ajou University participated in return for course credit in introductory and other psychology courses. All participants were native Korean speakers with normal uncorrected vision (or they wore soft lenses), and were naïve with regard to the aims of the experiment. The data from one participant had to be rejected because of excessive number of track losses, leaving 15 participants.

Materials. Sixteen experimental sentences and sixteen fillers were constructed for the experiment. There were four versions of each test sentence. One version of the test sentence had a center-embedded relative clause and contained the nominative case marker (-ka) in the initial NP (Rel-Nom); one version of the sentence had a complex NP and contained the nominative case marker in the initial NP (Com-Nom); one version of the sentence had a center-embedded relative clause and contained the delimiter marker (-man) in the first NP (Rel-Del); and finally, one version of the sentence had a center-embedded relative clause and contained the topic marker (-nun) in the initial NP. The following is an example of one complete set of test sentences:

Relative clause with the nominative marker (Rel-Nom)
 Gu Wunnchunsoo-ka chunksobu-lul selduk-han
 gunchuka-lul bipanhanda.
 The driver-Nom janitor-Acc persuade-CEM
 architect-Acc criticized
 (The driver criticized the architect who persuaded the janitor.)

(그 운전수가 청소부를 설득한 건축가를 비판했다)

Complex Noun Phrase with the nominative marker (Com-Nom)
 Gu Wunnchunsoo-ka chunksobu-lul selduk-han
 sasil-ka(-i) allyeicissta
 The driver-Nom janitor-Acc persuade-CEM
 fact-Nom was known.
 (The fact that the driver persuaded the janitor was known.)
 (그 운전수가 청소부를 설득한 사실이 알려졌다.)

Relative clause with the delimiter maker (Rel-Del)
 Gu Wunnchunsoo-man chunksobu-lul selduk-han
 gunchuka-lul bipanhanda.
 The driver-Del janitor-Acc persuade-CEM
 architect-Acc criticized
 (Only the driver criticized the architect who persuaded the janitor.)
 (그 운전수만 청소부를 설득한 건축가를 비판했다)

Relative clause with the topic maker (Rel-Top)
 Gu Wunnchunsoo-nun chunksobu-lul selduk-han
 gunchuka-lul bipanhanda.
 The driver-Top janitor-Acc persuade-CEM
 architect-Acc criticized
 (The driver criticized the architect who persuaded the janitor.)
 (그 운전수는 청소부를 설득한 건축가를 비판했다)

To facilitate comparison of the experimental results, most of nouns and verbs were selected from the previous experiment (Kim, 1999). A counterbalanced design yielded four lists of stimuli, such that only a single version of any particular test sentence was presented in each list. The fillers included a variety of structures, i.e., simple structure, coordinative sentence, and left-branching relative structure.

Apparatus. A PC with an A/D converter and a timer card controlled such experimental procedures as presenting sentences, recording reading times, and saving data. To display Korean characters on a monitor (with standard VGA), a Korean font library (‘Han’) was used. In the library, a syllable of Korean was represented in a 16X16 pixel matrix. All sentences were displayed on a single line with maximum length of 60 Korean characters. Participants were seated 90cm from the monitor and about 1.5 Korean syllables equaled 1 degree of visual angle.

Participants’ eye movements were recorded by a Fourward

Technologies Dual Purkinje Eyetracker (Generation V) that was interfaced with the PC. The eye tracker has a resolution of 10 min of arc, its signal was sampled every millisecond by the computer. Eye movements were recorded from the right eye, although viewing was binocular.

Procedure. Participants were told they would be reading a series of sentences presented on a computer screen. They were told to read for comprehension and that they would be asked a question about the sentence they just read. After each participant understood the procedure, a bite bar was prepared to minimize head movement. The eye tracking system was then calibrated to the participant. This procedure took about 10 minutes for each participant.

Each participant read 5 practice sentences to become familiar with the procedure. Before participants read each sentence, the experimenter checked to make certain that the eye-tracking system was accurately tracking the participant (i.e., the participant looked at the fixation boxes). If the checkup was good, the experimenter displayed the sentence. When the participant finished reading, he/she pressed a button that blanked the monitor, and then immediately the participant was asked a comprehension question. Two alternative answers appeared below the question, and the participant should choose one by a pressing corresponding button. Then the sequence resumed. After the practice sentences, each participant read the 32 sentences that were randomly ordered for each participant.

Results

An automatic procedure pooled short contiguous fixations. Individual fixation times less than 100ms or over 1000ms were considered to reflect noise and were excluded from the data analysis. Also, if the vertical fixation position was higher or lower by three characters, that fixation was ruled out in the data analysis.

A variety of reading time measures for each word region of each experimental sentence was calculated (see, Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). First-pass reading times are the sum of all consecutive fixation durations occurring within a region before leaving that region. *Second-pass reading times* are the sum of all fixations that readers make in a specific region after the eye passes that region. Re-reading times are the sum of all fixations that readers make in a specific region after the eye leaves that region in either a forward or a backward direction. These two measures showed almost the same pattern, so we reported only the re-reading times. *Second-pass times before going past the region* include only fixations in a specific region after leaving it to the left (backward), before going past the region (forward). Total reading times, the sum of all fixations in a specific region, were calculated too. But they showed almost the same pattern of reading times in each word position as the re-reading times, so they are not presented. *Regression-out probabilities* (i.e., percentage of trials where one or more legal fixations in a region were followed by a legal fixation to an earlier point in the sentence) and *regression-in probabilities* (i.e., percentage of trials where one or more legal fixations in a region were preceded by a legal fixation in a later region of the sentence) were also calculated.

First-pass reading times. The first-pass reading times of each word in four conditions are presented in Table 1. Every word in four conditions has the same number of syllables, except the fifth word. The reading times of the fifth word were divided by the number of syllables included in each word, and the syllable reading times were presented in parentheses.

As seen in <Table 1>, there were no differences in the ambiguous region (i.e., from the first word to the fourth word) among any of the conditions (all $F_s < 1$). The only exception was the reading times of the second word in the relative clause with the delimiter '-man' condition (Rel-Del). Its first-pass reading time was 774ms, and it was significantly

<Table 1> Mean first-pass times for each word in four conditions (ms)

	The	NP1(2 nd)	NP2(3 rd)	V-CEM ¹ (4 th)	NP3(5 th)	V-End (6 th)
Rel-Nom	182	620	400	414	496(124) ²	344
Com-Nom	180	639	480	494	394(132)	280
Rel-Del	152	774	451	454	468(117)	350
Rel-Top	159	593	444	444	515(129)	316

¹ CEM: Clause ending marker ² Syllable reading times

<Table 2> Mean second-pass times before going past the region for each word in four conditions (ms)

	The	NP1(2 nd)	NP2(3 rd)	V-CEM ¹ (4 th)	NP3(5 th)	V-End (6 th)
Rel-Nom	0	5	57	45	430(108) ²	117
Com-Nom	0	31	63	36	121(41)	66
Rel-Del	0	21	73	30	338(97)	116
Rel-Top	0	0	24	61	327(82)	90

¹ CEM: Clause ending marker ² Syllable reading times

<Table 3> Mean re-reading times for each word in four conditions (ms)

	The	NP1(2 nd)	NP2(3 rd)	V-CEM ¹ (4 th)	NP3(5 th)	V-End (6 th)
Rel-Nom	2	1389	1404	1088	1159(290) ²	117
Com-Nom	46	962	961	565	304(102)	66
Rel-Del	63	1276	1150	1025	891(223)	116
Rel-Top	22	949	995	845	813(203)	90

¹ CEM: Clause ending marker ² Syllable reading times

different from the fourth condition (Rel-Top) ($F_1(1,14) = 6.992, MSe = 35454.871, p=.019; F_2(1,15) = 4.530, MSe = 48479.181, p = .050$), and significantly different only in F_1 from the first condition (Rel-Nom) ($F_1(1,14) = 17.569, MSe = 10159.319, p=.001; F_2(1,15) = 2.781, MSe = 52910.792, p = .116$). There were no differences in the disambiguating region (i.e., the fifth head nouns and the final verbs) among any of the conditions.

Second-pass reading times before going past the region. As seen in <Table 2>, there were no differences on the ambiguous region among any of the conditions (all $F_s < 1$).

However, there was a significant difference between the first and the second condition on the disambiguating fifth word (108ms vs. 41ms) ($F_1(1,14) = 5.835, MSe = 5796.464, p=.030; F_2(1,15) = 5.331, MSe = 4721.733, p = .036$). That is, participants spent more time reading the disambiguating

region for the relative clause with the normative marker (Rel-Nom) compared to the complex noun phrase with the nominative marker (Com-Nom). The difference between the Rel-Nom and the Rel-Top (108ms vs. 82ms) was not significant.

Re-reading times. The re-reading times are presented in <Table 3>. It clearly shows the word-by-word processing differences among conditions, especially between the first and the second condition, and between the first and the fourth condition. Significant contrasts for each word are presented in <Table 4>.

The regression probabilities are presented in < Table 5 and 6>.

The participants showed significantly less regression-out probabilities in ambiguous third word of the topic marked condition (Rel-Top) compared to the normative marked

<Table 4> Contrasts among conditions in each word for re-reading times

Contrast(position)		2 nd	3 rd	4 th	5 th
Rel-Nom	$F_1(1,14)$	7.822	5.778	15.057	18.721
	MSe	17455.8	254657.2	136384.6	14221.4
	p	.014	.031	.002	.001
vs.	$F_2(1,15)$	7.681	13.189	11.762	22.974
	MSe	187803.9	121536.1	197516.3	12405.6
	p	.014	.002	.004	.000
Rel-Nom	$F_1(1,14)$	9.406	12.061		7.729
	MSe	153903.4	104296.5		116616.5
	p	.008	.004	N.S.	.015
vs.	$F_2(1,15)$	8.541	8.874		4.948
	MSe	173442.1	166746.7		228675.2
	p	.011	.009	N.S.	.042

<Table 5> Mean regression-out percentages for each word in four conditions

	The	NP1(2 nd)	NP2(3 rd)	V-CEM ¹ (4 th)	NP3(5 th)	V-End (6 th)
Rel-Nom	0	0	18	15	53	88
Com-Nom	0	0	18	10	40	88
Rel-Del	0	0	20	7	47	95
Rel-Top	0	0	3	12	51	89

¹ CEM: Clause ending marker

<Table 6> Mean regression-in percentages for each word in four conditions

	The	NP1(2 nd)	NP2(3 rd)	V-CEM ¹ (4 th)	NP3(5 th)	V-End (6 th)
Rel-Nom	100	95	75	48	20	0
Com-Nom	60	91	51	25	10	0
Rel-Del	100	90	76	45	24	0
Rel-Top	100	91	73	48	17	0

¹ CEM: Clause ending marker

condition (Rel-Nom) (respectively, 3% vs. 18%) ($F_1(1,14) = 4.846$, $MSe = 348.214$, $p=.045$; $F_2(1,15) = 5.256$, $MSe = 392.698$, $p = .037$). Also the participants showed significantly less regression-in probabilities in the third and the fourth word of the complex noun phrase condition (Com-Nom) compared to the other conditions (respectively, $F_1(3,42) = 3.473$, $MSe = 583.235$, $p=.024$; $F_2(3,45) = 3.938$, $MSe = 487.607$, $p = .014$, $F_1(3,42) = 3.676$, $MSe = 503.217$, $p=.019$; $F_2(3,45) = 2.521$, $MSe = 727.307$, $p = .070$).

Discussion

The purpose of the current experiment was, first, to examine resolving processes of ambiguities that are caused by such grammatical markings as the clausal ending marker and the delimitative marker, and secondly, to evaluate the predictions of the garden-path model and constraint-based accounts on the effects of Korean morphology in sentence parsing. Generally, the various measures of eye movements clearly showed the effects of the Korean morphological information on sentence parsing. As shown in the <Table 2 and 3>, the topic marker significantly reduced reading times, thus it confirmed the previous finding of Kim (1999). Furthermore, the first-pass times as shown in the <Table 1> showed the effects of the grammatical marking ambiguity, i.e., the longer fixation times on the NPs with the ambiguous delimiter '-man'. However, the more interesting aspects of the results are their theoretical implications.

The constraint-based accounts predict parallel activation and competition of two structures in the ambiguous region of the

relative clause with the nominative marker (Rel-Nom), and, as a result, longer reading times compared to that of the relative clause with the topic marker (Rel-Top). However, the strong version of the garden-path model predicts no difference between the two conditions. The results of the experiment went against the predictions of the constraint-based accounts and were more compatible with the garden-path model. The first-pass reading times <Table 1> of the ambiguous region (from the first word to the fourth word position) did not show any significant differences. Furthermore, the second-pass times before going past the region <Table 2> were not significantly different from each other in the two conditions. Although it is very hard to identify an initial parsing procedure with any eye-tracking measure (Altman, Garnham, & Dennis, 1992; Clifton, 2000), the two measures might be interpreted as reflecting the initial parsing effects because they were measured before encountering the disambiguation region (the fifth word, i.e., NP3).

The garden-path model with the minimal attachment principle predicts that the co-argument analysis will be performed in the ambiguous region of all conditions, and so there will be no difference among conditions. However, in the disambiguation region (the fifth word), the model predicts a difference. That is, the complex NP with nominative marker (Com-Nom) condition must show fast reading times compared to the Rel-Nom because reparsing is not required in the latter condition. As shown in <Table 1>, there was no significant difference between the two (124ms vs. 132ms) in the first-pass times of the disambiguating word. However, there was a significant difference between the conditions in the

second-pass times before going past the regions (108ms vs. 41ms in <Table 2>). Furthermore, all four words except the first and final words showed significant differences between the two in the re-reading times <Table 3 and 4>. The Com-Nom structure that might be parsed initially according to the minimal attachment principle showed shorter re-reading times from the second word to the fifth word position. These results confirmed that, in spite of the presence of various grammatical markers, the initial parsing process of Korean ambiguous structure basically follows the minimal attachment principle like English (Frazier & Rayner, 1982) and Dutch (Frazier, 1987). This conclusion also confirmed by the pattern of regression. As shown in <Table 6>, the Com-Nom condition significantly less regression-in percentages at the third and fourth word.

Furthermore, the results elucidate the processing of the Korean topic marker. As mentioned in the introduction, the topic marker is ambiguous. Topic marked NPs can be nominative (subject) or accusative (object). Nevertheless the eye fixation times showed that there were no differences between the unambiguous nominative condition (-*ka*) and the topic condition (-*nun*) in the first and second-pass times of the ambiguous region. However, despite the fact that the delimiter '-*man*' has the same ambiguity with the topic marker, participants spent more time reading the NPs that have a '-*man*' delimiter compared to the topic marked NPs and the nominative marked NPs (only F_1 was significant) in the first-pass times <Table 1>. From these results, we could conjecture that the topic marked NPs may be processed differently from the other delimiters, and they (especially, the first NPs of the sentence) may get a nominative case as a default. Although the NPs that have a '-*man*' delimiter showed longer first-pass times, reading times of other words after that were almost the same through the other three conditions <Table 1>. This suggests that the syntactic function (like subject or object) ambiguity of the NPs is immediately resolved and does not wait until the parser encounters disambiguating information (e.g., verb). Possibly the parser identifies the initial NP as being nominative as soon as an accusative NP is encountering.

Another question I tried to answer concerning the topic marker was whether it affects initial parsing procedures or reparsing routines. The finding that there were no differences between the Rel-Nom and the Rel-Top in the first- and

second-pass times <Table 1 and 2> and significant differences between the two conditions only in the re-reading times <Table 4> strongly support the reparsing interpretation of the topic marker effects (Kim, 1999). As shown in <Table 5>, the regression-out percentage also supports this conclusion. The third word of the Rel-Top condition showed significantly fewer regressions-out, as expected if the presence of the topic marker aids reanalysis, not initial analysis. The findings were not compatible with the constraint-based accounts that predicted the initial parsing effects of the topic marker. What we have to do next is to think about the possible reparsing routines and the topic marker's role during the reparsing. Why does the topic marker make reparsing easy? Does the topic marker just facilitate the reparsing routine? Does it provide information about what revision must be performed? This experiment was not intended to answer all these questions of reparsing. We may only speculate about some possible explanations that should be tested in further experiments.

Reparasing models can be grouped into two kinds: revision models and diagnostic models (for recent overviews, see Meng & Bader, 2000; Lewis, 1998). The former models emphasize the cost of structural revisions whereas the latter models emphasize the nature of symptom. An example of the revision models (Gorrell, 1995; Suh, 1994) argues that adding a structure or lowering a given structure does not cause reparsing difficulties if they maintain the precedence and dominance relations. In contrast to the revision models, the diagnostic model of Fodor and Inoue (1998, 2000) holds that all revision operations are associated with the same cost, if any. What can be of varying difficulty is to find out which revision operations are needed to arrive at a well-formed syntactic representation. The results indicating that the topic marker facilitated reparsing seem more compatible with the diagnostic model, because the revisions that must be performed in the Rel-Nom structure and the Rel-Top structure appear to be same: The first NP must be extracted from the embedded clause and should be the subject of the main clause. In these processes, we could think that the topic marker may provide more transparent information about the possible revision. In a similar vein, Sturt (1997) also argued that topicalization can make reparsing easy in Japanese. The roles of the topic marker and other delimiters in reparsing might be an interesting research issue for further studies.

In conclusion, an eye movement study of Korean clearly

indicates that an initial sequence of NPs is analyzed as co-arguments following the minimal attachment principle. In relative clause sentences, reanalysis effects are observed at the point of disambiguation including long re-reading times and an increased probability of making regressive eye movement. Reanalysis of the topic marked structures was easier than reanalysis of the nominative or delimitative marked structures. The finding suggests the diagnostic models of reparing.

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