A Parsing Paradox in Head Final Languages: Head-Driven vs. Incremental Parsing*

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1. Introduction

One of the most prominent topics in the sentence processing literature is the nature of on-line structure building: how ensuing words form into phrases and ultimately into a sentence. One critical observation underlying this question lies in the cross-linguistic variation of verb position in a sentence. In head-initial languages such as English, a verb comes relatively early in a clause. Thus, in on-line parsing, the following arguments can be immediately attached to the verb to form the phrase structure. In contrast, in head-final languages, such as Korean, a sentence begins with a series of NPs and the verb does not come until the end of the clause. This relatively late arrival of a verb in the sentence raises the question of how speakers of head final languages process strings of NPs. One view is that the NPs remain unattached until their licensing head arrives (i.e., verb), at which point the VP is projected and the NPs are integrated into the structure (Head-driven parsing: Pritchett, 1991, 1992). A more dominant view is that NPs are immediately integrated into a partial structure that is built based on the available local information (i.e., case markers), even before the relevant head arrives (Incremental parsing: Miyamoto, 2002; Yamashita, 1994, 1997; Kim, 1999; Shin 2006). This paper examines the evidence that has been presented in favor of incremental parsing and argues that although local (clausal level) parsing is incremental, the global (inter-clausal level) structural parsing in head-final languages could involve attachment delay, a characteristic feature of head-driven parsing.

2. Head-Driven vs. Incremental Parsing in Head Final Languages

The Head-driven parsing model (Pritchett 1991, 1992) assumes that grammatical principle that the lexical properties of heads are uniformly projected in the syntactic

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representation (e.g. the *projection principle*) is directly employed in language processing\(^1\). In a parsing model, this implies that a node (for example, VP) cannot be projected until its head (for example, verb) appears and thus its arguments’ attachment is not licensed until then. In terms of processing head-final languages, this implies that all NPs would remain unattached until the occurrence of the sentence-final verb.

On the other hand, the Incremental parsing model assumes that the parser predicts the argument structure of a verb, based on the arguments (Bader & Lasser, 1994; Miyamoto et al, 1999; Kamide & Mitchell, 1999 among others), and thus projects the underspecified node (in this case, VP). In terms of processing head-final languages, this implies that even though the underspecified node does not have its full lexical information, the partial information is enough to permit the arguments to be connected incrementally before the verb arrives (Inoue, 1991; Miyamoto, 2002). Thus, in contrast to the Head-driven parsing model, the Incremental parsing model holds that i) there is no delay in parsing and ii) parsing is incremental.

In fact, a number of psycholinguistic experiments have suggested that sentence processing is incremental and the parser is predictive, supporting the Incremental parsing model (Yamashita, 1994, 1997; Kim, 1999; Kamide & Mitchell, 1999; Mazuka et al., 2002; Miyamoto & Takahashi, 2002; Ueno & Kluender, 2003; Shin, 2006). One critical argument against Head-driven parsing comes from the processing patterns of sentences that involve a cue for an upcoming clause boundary.

(1) Ofisu-de shokuin-ga kakaricho-o [RC ti ocha-o dashita]
office-LOC employee-NOM manager-ACC tea-ACC served
Joseii-ni teineini shoukaishita
woman-DAT politely introduced
‘At the office, the employee politely introduced the manager to the woman who served the tea.’

(2) Ofisu-de shokuin-ga kakaricho-ni [RC ti ocha-o dashita]
office-LOC employee-NOM manager-DAT tea-ACC served
Joseii-o teineini shoukaishita
woman-ACC politely introduced
‘At the office, the employee politely introduced the woman who served the tea to the manager.’

(Miyamoto, 2002; p316-317)

For example, in (1), the second *o*-marked NP, ‘*tea-ACC*’ cannot be integrated into the same clause with its preceding NPs due to the *double o constraint* that restricts one *o*-marked NP per clause in Japanese (Kuroda, 1992). Accordingly, the Incremental parsing model predicts that a clause boundary would be posited at the second *o*-marked NP,

which causes a reading time (RT) slowdown at that position. On the other hand, the same word position in (2) is not predicted to elicit a slowdown because the preceding word is marked with dative case. This allows ‘tea-ACC’ to be integrated into the same clause with the preceding words. Therefore, at ‘tea-ACC’, (1) is predicted to be read more slowly than (2). At the head noun position, woman, however, Miyamoto (2002) argued that this earlier cue to the bi-clausality in (1) would facilitate processing and the sentence in (2) should show a RT slowdown due to mono- to bi-clausal reanalysis.

The Head-driven parsing model, on the other hand, does not predict any processing difference at ‘tea-ACC’ between sentences (1) and (2) because the head (i.e. verb) does not appear until one word later. Likewise, no processing differences between sentences (1) and (2) are predicted at the head noun position, woman because the head-to-argument relationship at that position is the same in both sentences.

Reading time results reported in Miyamoto (2002) supported the Incremental processing model in general: there was a slow-down to ‘tea-ACC’ in (1), when compared with the RT latencies for the same region in sentence (2). In addition, sentence (2) showed a significantly greater slowdown at ‘woman’ in comparison to sentence (1). The slowdown at these two positions was interpreted as supporting the idea that the parser utilizes the local information, such as case marking, in structure building and the parsing is incremental even in head-final languages (Miyamoto, 2002).

The slower reading of ‘tea-ACC’ in (1) seems to be strong evidence that case marking is actively utilized in structure building and that sentence processing is incremental. The processing difficulty at ‘woman’ in sentence (2), however, requires more clarification. Although it is clear that there is some sort of structural reanalysis at this position, the nature of reanalysis is not clear. Miyamoto (2002) attributed the slowdown at ‘woman’ in (2) to the processing difficulty associated with the mono- to bi-clausal reanalysis (see also Shin, 2006; Yamamoto, 1997 for a similar reasoning). This suggestion is based on the assumption that the parser initially interprets an incoming clause to be a root clause until it is forced to reanalyze the clause as a subordinate clause. However, it is not clear how reliable this assumption is in head-final languages. In head-initial languages, a sentence-initial subordinate clause is marked with subordinator, and thus an unmarked clause can be safely taken to be a root clause (cf. structural ambiguity in head-initial language: Frazier & Fodor, 1978). However, in head-final languages, subordinators come at the end of a clause and subordinate clauses frequently precede main clauses. Thus there is good possibility that the sentence-initial clause is a subordinate rather than main clause. For example, the Korean sentence in (3) illustrates an example where the first clause is a subordinate clause and the sentence is bi-clausal.

![Example sentence](3)

Given that this type of sentence configuration is frequent and reanalysis causes processing difficulty (Fodor & Frazier, 1980), the parser might delay the decision on the
status of the clause until the relevant information arrives (Inoue, 1991; cf. Mazuka & Lust, 1990), rather than performing frequent reanalysis. This hypothesis requires a different account of the processing difficulty at ‘woman’ in (2). One alternative account is that the reanalysis at ‘woman’ in (2) is related to rearranging the constituent structure and separating the initially connected NPs into different clauses as shown in (4) (cf. Fodor and Inoue 1998).

(4) \[
\{\text{Clause NP1 NP2 NP3 VP}\} \rightarrow \{\text{Clause1 NP1 NP2} \} \{\text{Clause2 NP3 VP}\}
\]

In other words, in (2), ‘tea-ACC’ was initially parsed as belonging to the same clause with the preceding words. Consequently, at the head noun position, ‘woman’, it gets disconnected from the preceding words and is integrated into a different clause. If this account is correct, there is no clear evidence that the parser initially attaches the incoming clause as a root clause.

To summarize, in head-final languages, local (clausal-level) parsing is incremental: NPs are incrementally parsed to form a clause, following information present on the case markers. However, the global (inter-clausal level) parsing may not be incremental: whether the attachment of the clause is immediately made as a root clause or the attachment is delayed until the relevant information arrives is not clear.

In this paper, I evaluate the Incremental and Head-driven parsing hypotheses at the clausal- and inter-clausal levels in Experiments 1 and 2 respectively, using the double nominative construction. In Korean, a double nominative construction occurs when the referents of NP1 and NP2 are in a close semantic relationship such as kinship, or whole-part (Na & Huck, 1993; Sohn, 1999). Syntactically, NP1 is analyzed as the Major subject of the sentential predicate of which NP2 is the subject (Yoon, 2004; but also see Yang 1972; Sohn 1986; Cho, 2000). Double nominative construction is interesting in processing, because even though theoretically it is possible to have two nominative marked NPs in a clause, the parser postulates a clause boundary at the second NP-NOM in an alienable double nominative construction (Shin, 2006).

(5) NP1-NOM NP2-NOM condition (Double nominative condition: NN)
ku hoysawon-i tongsayng-i phulo nongkwu-lul culkye ponta
that worker-NOM brother-NOM professional basket.ball-ACC often see
‘As for the worker, his brother often watches a professional basketball game.’

(6) NP1-GEN NP2-NOM condition (Genitive-nominative condition: GN)
ku hoysawon-uy tongsayng-i phulo nongkwu-lul culkye ponta
that worker-GEN brother-NOM professional basket.ball-ACC often see
‘The brother of the worker often watches a professional basketball game.’

In Experiment 1, there are two points of interest. According to the Incremental hypothesis, a clause boundary must be posited at NP2-NOM, ‘brother’ in sentence (5), which could elicit a RT slowdown. In contrast, in (6), the NP1 is marked with genitive case and thus NP2 can (and actually should) be in the same clause with the NP1. Hence, there is no need to posit a clause boundary. Thus, at NP2, sentence (5) would be read
more slowly than sentence (6). In addition, at the main verb position, sentence (5) should again elicit a significant slowdown compared to sentence (6). This is because sentence (5) should be reanalyzed back to being mono-clausal as the parser realizes that (5) is not actually bi-clausal at that position\(^2\) (for detailed discussion of this effect, please refer to Shin, 2006). In Experiment 2, the stimuli are built by changing the mono-clausal sentences in Experiment 1 to bi-clausal sentences. This is shown in (7).

(7) Experiment 1 sentences: NP1-NOM NP2-NOM V
    NP1-GEN NP2-NOM V
Experiment 2 sentences: NP1-NOM NP2-NOM V-COMP VP
    NP-GEN NP2-NOM V-COMP VP

The main interest in Experiment 2 lies in the nature of global parsing. If the parser indeed initially attaches the sentence-initial clause as a root-clause (Miyamoto, 2002), sentences without an early cue to the bi-clausality, as in Experiment 2 sentences corresponding to (6), should show processing difficulty at the embedded verb marked with a complementizer due to mono- to bi-clausal reanalysis. In contrast, if the parser delays the decision of the clause attachment as a main clause due to a lack of information (as is the case in these sentences), there should be no processing difficulty, since no reanalysis is being performed\(^3\). In addition, Experiment 2 investigates whether it could be the rearrangement of constituents that causes slowdown in sentence (2) in Miyamoto (2002). This is investigated by examining the processing difficulty at a sentential position that involves rearrangement of constituents but not a “mono- to bi-clausal” reanalysis.

3. Experiment 1
3.1 Method

Participants
Thirty five native speakers of Korean participated in the experiment (20 males, 15 females; age range: 21 to 37 years old, mean age=27). They were naive about the purpose of the experiment. Participants received $10 per hour for participation of the experiment.

Materials
There were two conditions in Experiment 1: double nominative condition (NN), (5) and genitive-nominative condition (GN), (6). In addition, Experiment 2 (three conditions) was conducted in the same experimental set-up for an ease of comparison across experiments. Thus, forty sets of the five conditions each were constructed and split into 5 lists using a Latin-square design. The sentences were intermixed with an unrelated 125 filler items and pseudo-randomized so that no two target sentences could appear in a row.

Procedures
The experiment was run on PsyScope in a sound-attenuated booth. Stimulus presentation was word by word, self paced, and non-cumulative. Each trial began with +, a fixation

\(^2\) This reanalysis also involves rearrangement of constituents from two different clauses into one.
\(^3\) Detailed and alternative analyses are presented in the discussion section of Experiment 2.
mark, in the center of the screen. When participants were ready for the next trial, they pressed a button, and the fixation mark was replaced by the first word of the sentence. To see the next word, the participants pressed the button and the first word was replaced with the next word in the center of the screen. The stimulus onset asynchrony from the appearance of one word to the next was recorded as the reading time of that word. After the final word of each sentence, participants answered a yes/no comprehension question for the preceding sentence.

**Data Analysis**
Statistical analyses were conducted on comprehension question response accuracy and RTs for each word position. Means and standard deviations were calculated for each subject across conditions. RTs that were beyond three standard deviations from the subject’s means were replaced with the subject’s mean value for that word position.

### 3.2 Results

**Comprehension question response accuracy**
The GN was comprehended better than the NN as measured by the question response accuracy (94 % vs. 90%). The difference was significant by an item analysis \( F_2(1, 39) = 1.92, p < .017 \) but not by a subject analysis \( F_1(1, 34) = 3.08; p < .089 \).

**Reading times**
Overall reading times for each word position is presented in Figure 1. At W3, the NN (1109 ms) was read significantly more slowly than the GN (953 ms) \( F_1(1, 34) = 4.68, p < .038; F_2(1, 39) = 4.58, p < .038 \). At W4, there was again a main effect of case marking. The NN (977 ms) was read significantly more slowly than the GN (819 ms) \( F_1(1, 34) = 4.71, p < .037; F_2(1, 39) = 4.42, p < .042 \). At W7, the sentence final position, there was again the main effect of case marking. The NN (1003 ms) were read more slowly than the GN (689 ms) \( F_1(1, 34) = 5.17, p < .029; F_2(1, 39) = 11.47, p < .0016 \).

**Figure 1 Experiment 1: RTs for each word position**

### 3.3 Discussion
As shown in Shin (2006), the parser initially processes the NN as a bi-clausal structure upon receiving the second nominative marked NP. The longer RT at W3 in the NN than in the GN indicates that the clause boundary was inserted due to the second nominative marked NP. However, upon processing the verb at W7, the parser has to reanalyze the
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NN back to a mono-clausal sentence, and hence a longer reading time at that position\(^4\). These experimental results thus suggest that the local parsing is incremental.

4. **Experiment 2**

The sentences in Experiment 2 were built by converting the mono-clausal sentences in Experiment 1 into bi-clausal sentences. The main goal of Experiment 2 is to test the Incremental and Head-driven parsing at the global (inter-clausal) level: is a sentence-initial clause attached immediately as a main clause as often assumed, or is the attachment delayed until the relevant information arrives? To address this issue, three types of bi-clausal sentences were constructed: i) constructions without an early cue to the bi-clausality (GNN) as in (8), ii) constructions with an early cue to bi-clausality (NND) as in (9), and iii) constructions with an early cue to bi-clausality and with a reanalysis of the constituents’ rearrangement (NNN) as in (10).

(8) NP1-GEN NP2-NOM NP3-NOM condition (GNN)

[ku hoysawon-uy tongsayng-i phulo nongkwu-lul culkye that worker-GEN brother-NOM professional basket.ball-ACC often ponta-ko] khephisyop-eyse Hyekswu-ka malhayssta see-COMP] cafe_at Hyekswu-NOM said ‘Hyekswu said at a cafe that the brother of the worker often watches a professional basketball game.’

(9) NP1-NOM NP2-NOM NP3-DAT condition (NND)

ku hoysawon-i [tongsayng-i phulo nongkwu-lul culkye that worker-GEN brother-NOM professional basket.ball-ACC often ponta-ko] khephisyop-eyse Hyekswu-eykey malhayssta see-COMP] cafe_at Hyekswu-DAT said ‘The worker told Hyekswu at a cafe that his brother often watches a professional basketball game.’

(10) NP1-NOM NP2-NOM NP3-NOM condition (NNN)

[ku hoysawon-i tongsayng-i phulo nongkwu-lul culkye that worker-NOM brother-NOM professional basket.ball-ACC often ponta-ko] khephisyop-eyse Hyekswu-ka malhayssta see-COMP] cafe_at Hyekswu-NOM said ‘Hyekswu said at a cafe that as for the worker, his brother often watches a professional basketball game.’

\(^4\) An alternative explanation for the longer RTs at W7 is related to the inherent parsing difficulty associated with the double nominative construction: at W7, the parser realizes that the clause is the double nominative construction, and focus reading of the double nominative construction (Yoon, 2004 among others) could lead to the longer RT (Birch, & Rayner, 1997). However, it should be noted that a presupposition of this hypothesis is that the parser reanalyzes the incoming clause back to a mono-clausal sentence. Therefore whether longer RT at W7 would be due to the focus reading or the reanalysis to mono-clausal sentence would not matter for the current purpose.
In the NND and NNN as in (9) and (10), a clause boundary would be inserted at the second NP-NOM even before the parser reaches the embedded verb marked with a complementizer. In contrast, in the GNN as in (8) there is no cue that the incoming clause is part of a bi-clausal sentence until the embedded verb position. If the parser attaches a sentence-initial clause as a root clause, the RTs to the embedded verb in the GNN should be longer than those in the NND and NNN due to mono- to bi-clausal reanalysis (Miyamoto, 2002). However, if the parser delays the attachment until the relevant information is reached, no difference is predicted among the three constructions. On the other hand, W9, Hyekswu-NOM in the NNN forces rearrangement of constituents. This is because NP1-NOM and NP2-NOM could be initially analyzed as a main and an embedded clause subject respectively but Hyekswu-NOM at W9, a clear main clause subject, forces double nominative clause reading where NP1-NOM and NP2-NOM occur in the same clause. In contrast, both the GNN and NND can maintain the initial structural analyses: in the GNN, NP1 and NP2 are in the same clause and in the NND, NP1 and NP2 are in different clauses. Thus, if the rearrangement of constituent causes processing difficulty, the RTs to W9, Hyekswu, in the NNN should be longer than those in the GNN and NND.

4.1 Results

**Comprehension Question Accuracy**
The overall correct comprehension question response rate was 92.2%. The comprehension accuracy rate for each condition did not differ among the conditions (GNN: 93.1%, NND: 90.8%, NNN: 92.5%) \[F_1(2, 34) < 1, p < .75; F_2(2, 39) < 1, p < .93\].

**Reading Times**
Overall RTs for each word position is presented in Figure 2. Within the embedded clause regions (W1 to W7), the NND and NNN conditions are identical. Therefore, the comparison was made between NP1-GEN and NP1-NOM, hence the GNN vs. NND & NNN. At W2, worker-GEN/NOM, the GNN (669 ms) was read faster than the NND and NNN (738 ms) and this difference was statistically significant \[F_1(1, 34) = 4.39, p < .04; F_2(1, 39) = 6.99, p < .01\]. At W3, brother-NOM, the GNN (960 ms) was again read faster than the NND and NNN (1064 ms). The difference was statistically significant by a subject analysis \[F_1(1, 34) = 4.45, p < .04\], but not by an item analysis \[F_2(1, 39) = 2.2, p < .14\]. Importantly, at W7, see-COMP, the embedded verb position marked with a complementizer, RTs to GNN as opposed to NND & NNN did not differ from each other (606 vs. 604 ms). At W9, Hyekswu-NOM/DAT, the statistical analysis was conducted on the residual RTs, because the NND has a dative marker, which is one syllable longer than the nominative marker. There was a main effect of construction type \[F_1(2, 34) = 4.06, p < .021; F_2(2, 39) = 4.63, p < .012\]. A pairwise comparison, however, showed that this statistical difference was caused by the NNN. The NNN was read significantly more slowly than the GNN \[F_1(1, 34) = 6.07, p < .018; F_2(1, 39) = 6.73, p < .013\] and the NND \[F_1(1, 34) = 3.65, p < .064; F_2(1, 39) = 6.16, p < .017\]. However, the GNN and NND did not differ from each other \[F_1(1, 34) < 1, p < .53; F_2(1, 39) < 1, p < .68\]. At W10, said,

\footnote{For methods, please refer to the section in Experiment 1.}
the sentence final word, there was again a main effect of the construction type \(F_1(2, 34) = 9.8, p < .0002; F_2(2, 39) = 8.8, p < .0004\]. A pairwise comparison showed that the GNN (495 ms) was read significantly faster than the NND (709 ms) \(F_1(1, 34) = 7.87, p < .008; F_2(1, 39) = 8.05, p < .007\) and NNN (893 ms) \(F_1(1, 34) = 13.16, p < .0009; F_2(1, 39) = 19.96, p < .0001\). The NND was also read significantly faster than the NNN by a subject analysis \(F_1(1, 34) = 5.27, p < .027\) but not by an items analysis \(F_2(1, 39) = 2.52, p < .12\).

**Figure 2 Experiment 2: RTs for each word position**

4.2 Discussion

As in Experiment 1, the results from Experiment 2 show that the second NP-NOM elicits longer RTs in comparison to NP-NOM following NP-GEN. Importantly, the three conditions (GNN, NNN, and NND) did not differ from each other at the embedded verb, see-COMP, and the following adverbial position, at a cafe. This suggests that the parser does not attach the sentence-initial clause as a root clause. If so, the GNN should have elicited longer RTs than the NNN and NND due to the reanalysis. This further indicates that the RT slowdown at ‘woman’ in sentence (2) is not due to a mono- to bi-clausal reanalysis as Miyamoto (2002) assumed. Alternatively, the longer RT at ‘woman’ in sentence (2) could be due to the rearrangement of constituents. This hypothesis was confirmed by residual RT differences at W9, Hyukswu-NOM/DAT among the three constructions. At W9, Hyekswu-NOM/DAT, given the Revision-as-Last-Resort Hypothesis (Fodor & Frazier, 1980), only the NNN requires rearranging of constituents. Accordingly, the NNN was read significantly more slowly than the corresponding GNN and NND.

Unlike Experiment 1, the results in Experiment 2 show significantly longer RTs to the first NP-NOM compared to NP-GEN. In fact, there were more items in Experiment 2, since at this position the NNN and NND were combined for the statistical analysis against the GNN, providing more statistical power. This effect could be related to the intrinsic processing difficulty of the nominative marker (Yamashita, 1994). In addition, the processing difficulty associated with the nominative marker (Lewis, 1993; Uehara, 1997; Lewis & Nakayama, 2002) could have affected the sentence wrap-up effect in the NNN and NND along with structural reanalysis for the NNN.

In sum, the following important observations were made.
There is a slowdown in RT at a NP that cannot be integrated into the same clause with its preceding NP (in this case, second NP-NOM) probably due to the clause boundary effect. There is no slowdown in RT when the parser encounters a cue to bi-clausality at verb with complementizer. Reanalysis involving rearrangements of constituents increase RTs.

Observation (11) has been accounted for in terms of the incremental parsing: local information is readily utilized to build a structure. Observation (12), however, seems to suggest that the parser does not readily attach the sentence-initial clause as a root clause but rather delays the decision until the appropriate information arrives, and hence no processing difficulty is associated with reanalysis. In other words, observations (11) and (12) together suggest that the parser may build a clause-level structure incrementally but does not attach the clause until it receives the clear information on the status of the clause (Inoue, 1991). In the sense of delay in attachment, this displays characteristics of head-driven parsing mechanisms (Pritchett, 1992). Yet, this hypothesis is not incompatible with the Incremental parsing either, because Incremental parsing relies on local information, and in some cases, cues to the clausal attachment might not be available until later. Korean sentences are ambiguous in many cases between structures starting with an embedded or main clause. Thus, if assuming the incoming clause is a main clause leads to frequent structural reanalysis, the parser might rather delay its decision until the right information arrives. In fact, cues might come in various forms, including the probability of a certain structure at a certain point. When the NP is marked with a topic marker rather than a nominative marker, it could signal that the clause is indeed a main clause rather than an embedded clause (Kim, 1999). Likewise, after a particular clause is identified as an embedded clause, the following clause could be analyzed as a main clause because, although theoretically multiple nested clauses are possible, the structure is not frequent and not preferred.

5. Conclusion

Case markers are actively employed in predicting the structure of an incoming clause, supporting the notion of an incremental parser (Miyamoto, 2002 among others). Thus, the sequence of nominative marked NPs lead to processing difficulty due to clause boundary insertion. However, Experiment 2 showed that even when there was no previous cue to the bi-clausality of the sentence, a verb marked with a complementizer did not lead to a processing difficulty of “mono- to bi-clausal” reanalysis. This evidence was taken to support that although clausal level parsing might be incremental due to information from case markers, the attachment of the clause itself could be delayed in the absence of proper local cues. However, since this hypothesis is based on a null effect, further research is needed to investigate processing consequences of this hypothesis. One important implication on the experimental design in head-final languages is that a prediction should not be made based on the assumption that all the “mono- to bi-clausal” reanalysis should elicit difficulty. It was suggested that when the “reanalysis” does not involve the rearrangement of constituents, there might be no processing difficulty.
References


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