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The effect of role shifting and expectation in the processing of center-embedded relative clauses in Korean*

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Yun, Hongoak, Yunju Nam, Duck Geun Yoo, and Upyong Hong. 2015. The effect of role shifting and expectation in the processing of center-embedded relative clauses in Korean. *Linguistic Research* 32(2), 313-353. The purpose of this study is to examine whether the effect of role shifting and expectation serves an independent function in predicting the degree of processing difficulty in center-embedded relative clauses in Korean. In Experiment 1, we observed that head NPs modified by relative clauses, regardless of the order of constituents (i.e., $SO_{REL}V$ or $OS_{REL}V$), took longer to read when the roles corresponding to the traces of the head NPs needed shifting than when they needed not. In Experiment 2, we found that probabilistic distributions pertaining to the head NPs differed as a function of whether or not role shifting for the NPs was required. The mixed-effect models with expectation playing as a predictor on processing difficulty behaved similarly to the model with role shifting being a predictor on processing difficulty. However, mediation analyses in which expectation and role shifting were considered in the same model yielded that the effect of expectation subsumed that of role shifting when constituents were canonically ordered but not when they were scrambled. We claim that the fundamental function of expectation in association with role shifting is additionally effective only when sentence complexity is not extremely severe. **(Konkuk University · Hankuk University of Foreign Studies)**

Keywords role shifting, expectation, Korean center-embedded relative clauses

1. Introduction

Shifting existing representations that have been constructed in mind is more cognitively costly than keeping them as they have been constructed. For example,

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imagine a driver who is attempting to change a lane from where he has been driving all the way. The driver has to process information reflected in the side and back mirrors, look to the front, back, and the side, check his blind spot for a stable gap in traffic, compute a toy physics to make a decision, turn on his signal to tell other drives, check blind spot again, and finally do a lane-change. At an instant moment after he decided not to keep driving in the same lane, the driver challenges himself to accommodate the representations in his mind with a large amount of new information with his full attention.

In a similar vein, comprehenders' cognitive cost to shifting the representations that have been constructed during comprehension could elicit additional processing difficulty. The difficulty can be viewed in several aspects. On the one hand, it is related to the phenomenon called role shifting. For instance, in Example (1a), the agent of the chasing event in the relative clause (i.e., *the dog*) is still an agent of the kicking event in the main clause. Once comprehenders represent *the dog* chasing the cat, they keep having *the dog* kicking the horse. In contrast, *the dog* in Example (1b) takes a role as a patient in the chasing event where *the cat* plays a role as an agent. Later on, the role of *the dog* becomes an agent in the kicking event. Comprehenders once represent *the dog* to be chased by the cat, but then they have to shift the exiting representations of *the dog* as a patient into the new one where *the dog* as an agent now kicked the horse. If comprehenders' cognitive cost to such a role shifting associated with *the dog* psychologically exists, sentences like (1b) would take longer to process than those like (1a) (see similar claim in MacWhinney & Pie, 1988).[1]

(1) a. The dog that chased the cat kicked the horse.
b. The dog that the cat chased kicked the horse.

On the other hand, the difficulty associated with shifting comprehenders' representation can appear as a function of expectation in a way that in encountering unexpected information, comprehenders have severe processing difficulty in

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1 For this particular example, there are other possible reasons (e.g., memory load, plausibility, or frequency) to account for why sentences like (1a) are easier to understand than sentences like (1b). We presented the examples (1a-b) to show that information shifting and processing difficulty are closely related in language comprehension.

accommodating what they have constructed during comprehension by shifting from expected information to unexpected information (c.f., Hale, 2001; Levy, 2008; Levy, Fedorenko, & Gibson, 2013).[2] Example (1b) might be more difficult to process than Example (1a) because on reading the first constituent, *the dog*, it might be much more likely to encounter verbs, *chased* as illustrated in (1a), than to encounter immediately another constituents, *the cat* as illustrated in (1b) (Mitchell, Cuetos, Corley, & Brysbaert, 1995), due to the fact, in part, that SRCs are much more frequent than ORCs (Roland, Dick, & Elman, 2006). Shifting from expected information to unexpected information could be difficult because unexpected information has already been pruned away and thus it is enormously difficult to access already-pruned information (Jurafsky, 1996). Comprehenders' expectation tends to be satisfied more with sentence constructions like (1a) than sentence constructions like (1b).[3]

To be brief, whether or not role shifting regarding NPs is required (i.e., whether or not to reorganize or reanalyze what has been represented during comprehension) might not be a unique cause to account for the degree of difficulty in the processing of sentences like (1a-b). Rather, the degree of processing difficulty might also be affected by how well upcoming information fits into comprehenders' representations being constructed during comprehension. In this study, we attempt to explore what would underlie the difficulty of sentence comprehension, in terms of comprehenders' shifting their representations that they have constructed. Would it be driven as a function of the necessity of role shifting, the degree of expectation, or both? For our aim, we focused on the integration of head noun phrases (NPs) modified by center-embedded relative clauses into sentences in Korean.

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2 In this study, it is not our primary interest to restrict specific cognitive resources like attention, memory, or others as a fundamental mechanism for expectation. The surprise or difficulty due to the failure of expectation could be attributed to the nature of selective attention (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman, 1964) as found in visual perception studies (Posner, 1980; Posner, Snyder, & Davison; 1980) or the nature of long-term memory structure as found in comprehension (Fedemeier & Kutas, 1999; Jurafsky, 1996).

3 We do not intend to distinguish the anticipation from integration. An easier processing might occur presumably because expected words or structures activated by context in advance are easier to be retrieved from memory or because expected words or structures are easier to be integrated into the representations being constructed during comprehension.

1.1 Unsolved issues in the processing of center-embedded relative clauses

It has been widely agreed that subject-extracted relative clauses (hereafter, SRC), as in (1a), are easier to process than object-extracted relative clauses (hereafter, ORC), as in (1b), in English (Gibson, Desmer, Grodner, Watson, & Ko, 2005; King & Kutas, 1995; O'Grady, 1997; Traxler, Morris, & Seely, 2002), German (Mecklinger, Schriefers, Steinhauer, & Friederici , 1995; Schriefers, Friederici, & Kuhn, 1995), and head-final languages like Japanese (Miyamoto & Nakamura, 2003) and Korean (Kwon, Gordon, Lee, & Kluender, 2010; O'Grady, Lee, & Choo, 2003).

Several approaches have attempted to account for the asymmetry of processing difficulty observed across SRCs and ORCs. For example, according to a memory-based approach, comprehenders' memory load is harder in the processing of ORCs than in that of SRCs because the number of yet-to-be-integrated arguments that comprehenders keep holding in their working memory is higher in ORC sentences than SRC sentences (Gibson 1998; 2000). A frequency-based approach takes its special attention on the information that comprehenders experience and the approach claims that the easier processing of SRCs relative to ORCs was due to the higher frequency of SRC sentences than ORC sentences which would elicit higher expectation in encountering SRC type of sentences than ORC type of sentences (Hale, 2001; Levy, 2008; Mitchell et al., 1995; Roland et al., 2006).

A perspective-shifting approach (MacWhinney, 1982) also predicts that SRCs are easier to process than ORCs in subject-modifying relative clauses. In this approach, shifting roles for head NPs (due to the differences of thematic roles for them) requires readers' cognitive efforts whenever it happens and more frequent involvement in role shifting during processing often result in higher degree of processing difficulty. As illustrated with the examples of (1a-b), comprehenders need to conduct role shifting more frequently in the processing of ORCs than in that of SRCs (MacWhinney & Pie, 1988). However, the prediction by the perspective-shifting approach was not always observed. Its prediction emerged neither in the processing of Chinese relative clause (Hsiao & Gibson, 2003) nor in that of Russian relative clause (Levy et al., 2013). Similarly, the effect associated with role shifting did not seem to appear at all times in the processing of Korean relative clauses, neither. For instance, consider the example sentences of (2a-f) that Kwon et

al. (2010) used in their study. In this study, modifier types were manipulated; sentences of (2a-b) are subject-modifying relative clauses. While sentences of (2c-d) are scrambled object-modifying relative clauses, sentences like (2e-f) are center-embedded object-modifying relative clauses. In each type of modifiers, the type of relative clauses was either a SRC (i.e., 2a, 2c, and 2e) or an ORC (i.e., 2b, 2d, and 2f).

(2) a. [t_i yumyenghan sengacka-lul chwukce-ey chotayha-n]
[t_i famous vocalist-ACC festival-to invited-ADN]
cihwuycai-ka uywon-ul kongkongyenhi moyokhay-ss-ta.
conductor-NOM senator-ACC publicly insult-PST－DECL
'The conductor who invited the famous vocalist to the festival publicly insulted the senator.'

b. [yumyenghan sengacka-ka chwukce-ey t_i chotayha-n]
[famous vocalist-NOM festival-to t_i invited-ADN]
cihwuycai-ka uywon-ul kongkongyenhi moyokhay-ss-ta.
conductor-NOM senator-ACC publicly insult-PST－DEC
'The conductor who the famous vocalist invited to the festival publicly insulted the senator.'

c. [t_i yumyenghan sengacka-lul chwukce-ey t_i chotayha-n]
[t_i famous vocalist-ACC festival-to invited-ADN]
cihwuycai-lul uywon-i kongkongyenhi moyokhay-ss-ta
conductor-ACC senator-NOM publicly insult-PST-DECL
'The senator publicly insulted the conductor who invited the famous vocalist to the festival.'

d. [yumyenghan sengacka-ka chwukce-ey t_i chotayha-n]
[famous vocalist-NOM festival-to t_i invited-ADN]
cihwuycai-lul uywon-i kongkongyenhi moyokhay-ss-ta
conductor-ACC senator-NOM publicly insult-PST-DECL
'The senator publicly insulted the conductor who the famous vocalist invited to the festival.'

e. Yumyenghan cihwuyca-ka [t_i sengacka-lul chwukce-ey chotayha-n]
famous conductor-NOM [t_i vocalist-ACC festival-to invited-ADN]
uywoni-ul kongkongyenhi moyokhay-ss-ta

senator-ACC publicly insult-PST-DECL
'The famous conductor publicly insulted the senator who invited the vocalist to the festival.'

f. Yumyenghan cihwuyca-ka [sengacka-ka chwukce-ey t_i chotayha-n]
famous conductor-NOM [vocalist-NOM festival-to t_i invited-ADN]
uywoni-ul kongkongyenhi moyokhay-ss-ta
senator-ACC publicly insult-PST-DECL
'The famous conductor publicly insulted the senator who the vocalist invited to the festival.'

Note that the thematic role corresponding to the trace of the head NP in the relative clause of (2a) is an agent. When the NP explicitly occurs at the head position, it is attached with a subject case marker, *–ka*, suggesting that the NP is an agent in the main clause. Comprehenders in (2a) keep the same role interpretation associated with the head NP as an agent without making any changes. However, the role for the trace of the head NP in the relative clause of (2b) is a patient. Then, at the position of the head NP, it appears as an agent with its being attached with a subject case marker *–ka*. At that position, comprehenders in (2b) have to shift the role interpretation for the NP from a patient to an agent. According to the perspective-shifting approach, it should be more difficult to integrate the head NP into the sentence (2b) than the sentence (2a). Similarly, the integration of the head NP into the sentence (2d) would be easier than that of the head NP into the sentence (2c). When the phrases of relative clauses are center-embedded as in (2e-f), there will be more difficulty in integrating the head NP into the sentence (2f) than into the sentence (2e). Thus, given the effect of role shifting, the processing benefit of SRCs over ORCs would occur only in sentences like (2a-b) but not appear in sentences like (2c-f). Kwon et al. (2010) observed the processing benefit of SRCs over ORCs when relative clauses modified subject nouns, as in (2a-b), and object nouns, as in (2c-d), but not when object-modifying relative clauses were center-embedded, as in (2e-f). The effect of role shifting did not fully emerge in Kwon et al.'s study.

Unlike Kwon and her colleague, Lee (1995) used only center-embedded relative clauses, as in (3a-b), in which the constituents were canonically ordered like (3a), but they were scrambled like (3b). The role associated with the head NP (i.e., *pephakca*) of (3a) was a patient in the both clauses, whereas the NP of (3b) was a

patient in the nested relative clause but an agent in the main clause. Lee observed that the sentences like (3b) where role shifting for the head NPs was necessary were more difficult to process than the sentences like (3a) where role shifting for the head NPs was not necessary. Lee's results supported the claim of the perspective-shifting approach.

(3) a. Kenchwykka-ka [[ku wuncenca-ka t_i kyengmyel-ha-n] ephakca$_i$-lul]
Architect-NOM the driver-NOM despise-REL lawyer-ACC
miwe-han-ta.
hate.
'The architecture hated the lawyer who the driver despised.'
b. Kenchwykka-lul [[ku wuncenca-ka t_i kyeungmyel-ha-n] pephakca$_i$-ka]
Architecture-ACC the driver-NOM despise-REL lawyer-NOM
miwe-han-ta.
hate.
'The lawyer who the driver despised hated the architect.'

Nonetheless, Lee's study has some concerns. Sentences like (3b) were scrambled but sentences like (3a) were not, hinting that other factor might also be involved in. Lee's results might show not the function of role shifting but that of scrambling. In any way, given the inconsistency between Kwon et al. (2010) and Lee (1996), it is not clear whether or not processing difficulty due to role shifting is actually real.

1.2 Possibility on the function of expectation

One of recent approaches in sentence processing explores how probabilistic human mind works during online sentence comprehension (Chater & Manning, 2006; Hale, 2001; Jaeger, 2010; Jurafsky, 1996; 2003; Levy, 2008). In this approach, one of the powerful theories, the surprisal model claims that the degree of difficulty in the integration of a word into a sentence is proportional to the degree to which the word is expected given the context, as shown in Equation (1). A number of studies have demonstrated that word predictability, measured as a word's conditional probability, predicted the degree of processing difficulty at the position that the word occurred (Bicknell, Elman, Hare, McRae, & Kutas, 2010; Boston, Hale, Patil, Kliegl,

& Vasishth, 2008; Boston, Hale, Vasishth, & Kliegl, 2011; DeLong, Urbach, & Kutas, 2005; Demberg & Keller, 2008; Hale, 2001; Levy, 2008; Pado & Crocker, 2009, Roland et al., 2012; Staub, 2010; 2011; Vasishth, 2003). For example, using the sentence, *The horse raced past the barn fell*, Hale (2001) demonstrated that the degree of surprisal (i.e., negative log-transformed conditional probability) corresponding to the verb, *fell*, sharply increased, indicating that comprehenders did not expect to encounter the main verb at the sentence-final position and might have had extreme difficulty in the integration of the unexpected verb, *fell*, into the sentence fragment.

$$difficulty \propto -\log P\,(w_i\,|w_{1\ldots i-1}, \mathrm{CONTEXT}) \qquad \text{Equation (1)}$$

The difficulty in the integration of a word into a sentence is also affected by the extent of uncertainty that exists at the position that the word appears. Equation (2), known as Shannon's Entropy, indicates the extent of uncertainty based on the probability distribution of possible choices that could occur at the time of *t* at a sentence. Previous studies have estimated how much the extent of uncertainty could be reduced word by word as the information that each word conveys is incrementally built up. Equation (3) represents the reduced amount of uncertainty at the time of *t*+1 in a sentence after a word that has occurred at the time of *t* has been processed.

$$H\,(X; w_1^t) = -\sum_{x \in X} P\,(x|w_1^t)\,\log \mathrm{P}(\mathrm{x}|w_1^t) \qquad \text{Equation (2)}$$

$$\Delta H\,(X; w_{t+1}) = H(X;\, w_1^t) - \mathrm{H}\,(\mathrm{X};\, w_1^{t+1}) \qquad \text{Equation (3)}\ [4]$$

This so-called Entropy Reduction Hypothesis aims to test that as each word is cumulatively introduced in a sentence, the extent of uncertainty on the upcoming information is reduced which in turn would contribute to the reduction of processing difficulty (Frank, 2010; 2013; Hale, 2006). Existing studies demonstrated that the difficulty of processing a word in a sentence was reduced in proportion to the

4 Equation (2) and Equation (3) are taken from Frank (2013).

reduced extent of uncertainty between at the very point that the word occurred and at the previous point that the previous word had been introduced, by computing uncertainty based on part-of-speech assignments (Frank, 2010), individual words (Frank, 2013), and context-free syntactic tree structures (Hale 2006).

Now, suppose sentence fragments like (4a-b) taken from Lee (1996). In (4a), the consecutive presentation of two constituents attached with a subject case marker, *-ka*, cues that there should be a clause boundary between the two words. Whereas, in (4b), the presentation of an object case marker, *-lul*, together with a subject case marker, *-ka*, suggests that having a clause boundary between the two words is not necessary. If a NP appears after the fragment (4a), the whole fragment consists of a sentence-initial subject and a center-embedded relative noun or adverbial clause, suggesting that the head NP should be extracted from the fronted clause. However, given the sentence fragment (4b), if a NP continues, the fragment can be a noun clause or a relative noun/adverbial clause, depending on the meaning of the NP. If the fragment becomes a noun clause, the NP is not extracted from the fronted clause, but if the fragment becomes a relative clause, the NP should be extracted from fronted clause.

(4) a. Kenchwykka-ka ku wuncenca-ka kyengmyel-ha-n _____
Architect-NOM the driver-NOM despise-REL _____
b. Kenchwykka-lul ku wuncenca-ka kyeungmyel-ha-n _____
Architecture-ACC the driver-NOM despise-NOM/REL _____

At the position, marked as _____, the likelihood that the head NP is extracted from the fronted clause tends to be higher in (4a) than in (4b). The degree of uncertainty about what is coming up next could be higher in (4b) than in (4a). This would be because possible choices for an upcoming position are more likely widely distributed in (4b) than in (4a). Thus, the expectation to encounter an extracted head NP is higher in (4a) than (4b). By the expectation-based approach, if an upcoming word is an extracted NP, it should be easier to process in (4a) than (4b), because the upcoming information fits well into the constructions that comprehenders have developed during comprehension in the given contexts like (4a) than in the given contexts like (4b). Comprehenders do not need to shift their representations to unexpected information.

1.3 Summary of our study

We had three major goals. One goal was to clarify whether processing difficulty due to role shifting would actually exist. Another goal was to test the effect of expectation by using the exactly same materials and behavioral data and further to compare the results from the expectation-based model to those from the role-shifting model. Our third goal was to explore the relationship between role shifting and expectation. In particular, we were interested in examining which effect would mediate which effect in predicting the degree of processing difficulty. In Experiment 1, we tested the effect of role shifting during sentence processing. For this, we revised Lee's experimental design and materials and ran a self-paced moving window comprehension experiment. In Experiment 2, we first conducted a cloze task to constitute the probabilistic distribution corresponding to target words of our experimental stimuli. The degree of expectation was computed with two types of probabilistic measurements: conditional probability of a target constituent and the degree of uncertainty at a given target position. Then, a mixed-effect regression model was conducted to test the effect of expectation on the reading times that we obtained from Experiment 1. Finally, we investigated whether the effect of expectation would mediate that of role shifting, and *vice-versa*, through mediation analyses.

2. Experiment 1

2.1 Obtaining behavioral responses

The purpose of Experiment 1 was to observe comprehenders' processing behaviors in the integration of words into sentences, depending on whether thematic roles corresponding to the words were required to be shifted or not. We hypothesized that the processing difficulty of words would be increased when role shifting associated with the words was required. We also hypothesized that the effect of role shifting would emerge when sentences were both scrambled and canonical. We might be able to observe that the difficulty due to role shifting might be bigger in scrambled sentences than canonical sentences. In order to test our hypotheses, we

conducted a 2 Role Shift (Yes, No) x 2 Word Order (Canonical, Scrambled) experiment.

Participants. 65 Konkuk University students (27 male and 38 female) took part in an online reading study. The mean age of the participants was 21.66 years old. The participants received 5,000 won to compensate for their participation.

Materials. Center-embedded relative noun clauses, as shown in (5a-d), were used. Each sentence consisted of five regions, marked by "|". The underlined words that were the fourth word of each sentence were crucial for our study. The experimental materials differed in two ways. First, experimental stimuli differed depending on whether the thematic roles corresponding to head NPs modified by relative clauses were required to be shifted or not. That is, this was the matter of whether the roles for the traces of the head NPs in relative clauses were consistent or inconsistent to the role information that the case markers attached to the head NPs represent in main clauses. In sentences like (5a) and (5c), the thematic roles corresponding to the NPs were the same in the fronted relative clauses and in the main clauses. For example, the trace for *Haywen-ilul* in (5a) in the blaming event took a patient role and she was also a patient attached with an object case marker in the forgiving event. In contrast, in sentences like (5b) and (5d), the thematic roles corresponding to the NPs at the 4th region were different between when they were in the fronted relative clause and when they were in the main clause. For example, the trace for *Haywen-ilul* in the blaming event of (5b) was an agent but she became a patient attached with an object case marker, *-lul*, in the forgiving event. Second, our stimuli differed by whether the constituents were canonically ordered or scrambled. The constituents of the sentences like (5a-b) were canonically ordered (i.e., $SO_{REL}V$ order), whereas those of the sentences like (5c-d) were scrambled by object nouns being fronted to the beginning of the sentences (i.e., $OS_{REL}V$ order).

(5) a. No Role Shift (Same Role), Canonical order:
Wupin-ika | *Kangho-ka* | *pinanha-n* | *<u>Haywen-ilul</u>* |
Wupin-NOM [Kangho-NOM t_i blame-REL] Haywen$_i$-ACC
yongse-hayss-ta.
forgave.
'Wupin forgave Haywen who Kangho blamed.'

b. Yes Role Shift (Different Role), Canonical order:

Wupin-ika | *Kangho-lul* | *pinanha-n* | *Haywen-ilul* |
Wupin-NOM [t_i Kangho-ACC blame-REL] Haywen$_i$-ACC
yongse-hayss-ta.
forgave
'Wupin forgave Haywen who blamed Kangho.'

c. No Role Shift (Same Role), Scrambled order:
Wupin-ilul | *Kangho-lul* | *pinanha-n* | *Haywen-ika* |
Wupin-ACC [t_i Kangho-ACC blame-REL] Haywen$_i$-NOM
yongse-hayss-ta.
forgave
'[Haywen who blamed Kangho] Wupin forgave [____].'

d. Yes Role Shift (Different Role), Scrambled order:
Wupin-ilul | *Kangho-ka* | *pinanha-n* | *Haywen-ika* |
Wupin-ACC [Kangho-NOM t_i blame-REL] Haywen$_i$-NOM
yongse-hayss-ta
forgave
'[Haywen who Kangho blamed] Wupin forgave [____].'

24 sets of experimental materials were counterbalanced across four presentation lists, by using a Latin-squared method. The experimental sentences were pseudo-randomly intermixed with 60 filler sentences. The syntactic structures of these fillers were various. Some filler sentences had the forms of simple active declarative sentences, compound sentences, or complex sentences. Because we asked participants to reject sentences at the point that they thought the sentences did not make sense while they were reading sentences, we included non-sensible sentences. All experimental sentences were likely to be judged sensible. The fillers were either sensible or nonsensical. 37% of the distractor sentences, which were 26% of the total number of trials, were designed not to make sense. Nonsensical filler sentences were rejected due to diverse reasons. Some sentences did not make sense due to semantic or pragmatic reasons. Some sentences had to be rejected due to the violations of grammar, tense, or agreements.

Procedure. A self-paced moving-window procedure with an incremental judgment task was used. This judgment task was used to increase the sensitivity of the methodology to subtle effects that might not be observed in a straight reading

paradigm (Mauner, Tanenhaus, & Carlson, 1995). At first, participants saw a row of dashes and white spaces on a computer monitor. The dashes corresponded to all of the black characters of each stimulus sentence. Stimulus sentences were presented on one line. Participants pressed a “Yes” key marked on a computer keyboard to reveal the first region. This caused the dashes corresponding to this region to be replaced by words. To reveal the next region, participants again pressed the “Yes” key. This second press caused the first region to revert to dashes while revealing the second region. Participants kept pressing the “Yes” key to read each subsequent region as long as the sentence they were reading made sense to them syntactically, semantically, and pragmatically. If at any time a sentence did not make sense, participants pressed a “No” key. The “No” response immediately terminated the current trial and initiated the next trial. “Yes” Reading times and “No” judgments were collected as dependent variables for each region. Before the experiment began, participants were asked to read the instructions that described the task with some examples. After reading the instructions, they completed five sensible trials and five nonsensical practice trials to familiarize themselves with the task and the response keys.

2.2 Results

The self-paced reading paradigm with a judgment task yielded two dependent variables: the “No” judgments and the reading times for each segmented region to which participants pressed “Yes”. The “No” judgments were used to test how grammatically tolerant readers would be in the integration of words into sentences. The “Yes” reading times measured how much difficulty readers would have in the integration of words into sentences. The longer reading times were to refer to the more difficulty. Because we were interested in examining processing difficulty at the position of modified NPs, we analyzed the “No” judgments and “Yes” reading times at that region.

No judgments. Before we analyzed the No responses, we had to remove 4 participants because they rejected more than 70% of the sentences. We thought that they did not read our stimuli in a normal way. It resulted in the removal of .03 % of the total number of the No responses.

In order to see a brief view of No rejections across conditions, we tabulated the

adjusted of No judgments at each region of a sentence for each participants, by using the procedure outlined in Boland, Tanenhaus, and Garnsey (1990). The adjusted no percentages for each sentence trial were computed by dividing the number of "No" judgments at a given region by the number of remaining opportunities that a participant had for responding "No" in that sentence. Mean adjusted no percentages were then computed by condition and region for each participant. Table 1 displays the means and standard deviations of adjusted no percentages in each region across all conditions.

Table 1. The means and standard deviations of adjusted No judgments for each condition at each region

Condition	Word 1	Word 2	Word 3	Word 4	Word 5
NoRoleShift_SOV	0	10.09	18.18	13.77	18.82
	(0)	(20.02)	(28.18)	(27.10)	(31.70)
YesRoleShift_SOV	0	0.22 (1.91)	0.66 (4.25)	9.30	11.65
	(0)			(20.56)	(24.84)
NoRoleShift_OSV	0	13.38	24.98	22.96	38.07
	(0)	(20.91)	(30.53)	(32.11)	(39.49)
YesRoleShift_OSV	0	1.75 (6.43)	3.05 (8.92)	34.63	37.90
	(0)			(35.40)	(36.84)

Because categorical variables like yes-no judgment were rather to be analyzed in a linear mixed-effect model (Jaeger, 2008), we conducted a linear mixed-effect logistic model in which no responses observed at our target region (i.e., modified NPs at Region 4) were examined as dependent variables. The R statistics program (version 3.1.2, R Development Core Team, 2014) and languageR libraries (version 1.4.1, Baayen, 2013) were used. The judgment responses of target phrases that participants made were submitted as dependent variables to the mixed-effect regression. "Yes" responses were coded as 0 while "No" responses were coded as 1. Three fixed factors were included in this model as predictors: Word Order, Role Shift, and the interaction between Word Order and Role Shift. First, Word Order referred to the order of subjects and objects of sentences. 1 was used for the scrambled sentences (i.e., OSV condition), whereas 0 was used for the canonical sentences (i.e., SOV condition). Second, Role Shift referred to whether the thematic roles corresponding to the modified NPs were the same between when they were in

the relative clauses and when they were in the main clauses. 0 was used to mark when the role shifting was not required (i.e. No Role Shift condition) but 1 was used to mark when role shifting was required (i.e., Yes Role Shift condition). Participants and items were included as random factors. We simplified the initial fully crossed and fully specified random effect structure to yield the maximally justified random structure, as discussed by Jager (2009) and Baayen, Davison, and Bates (2008). An initial fit for the random intercept and slopes model performed. Approximately 3% out of the overall data were removed from the final model by Baayen's (2008) outlier removal procedure. Specifically, no rejections with a standardized residual at a distance greater than 2.5 standard deviations from zero were removed. The results of our model are displayed in Table 2. The correlations of all variables in our model were under .3 except the interaction between the role shifting and the interaction terms (r = .58).

Table 2. Results from the model using linear mixed-effect logistic regression

	Coefficient	S.E.	z-score	p-value
Intercept	-5.28	.74	-7.17	.00
Word Order	-4.89 (-2.44)	.49	-9.88	.00
Role Shift	.06 (.03)	.36	.16	.87
Word Order * Role Shift	-2.72 (-.67)	.69	-3.97	.00

Note. All predictors were centered. Parenthetical values next to the coefficients are standardized coefficients from a version of the model with standardized predictors.

The main effect of Word Order was observed, indicating that scrambled sentences were rejected more than canonically ordered sentences at the region that modified nouns appeared (see similar patterns in Lee, 2014). The main effect of Role Shift did not appear, meaning that comprehenders did not reject sentences depending on whether the thematic roles of the modified NPs were required to be shifted or not. Importantly, the significant interaction between Role Shift and Word Order revealed (see Figure 1). To unpack the interaction, we split the data by Word Order and tested the simple effect of Role Shift in each split data. The simple effect of Role Shift did not reach to the significant level in both when sentences were scrambled (Coefficient = .89, S.E. = .59, z = 1.52, p = .13) and when sentences were canonically ordered (Coefficient = -14.11, S.E. = 18.53, z = -0.76, p = .45). Nonetheless, the significant interaction between Role Shift and Word Order indicated

that the sentences in the OSV condition were rejected more when role shifting was required, whereas the sentences in the SOV condition were rejected more when role shifting was not required.

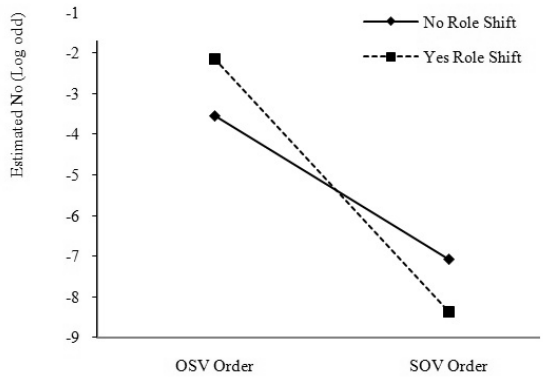


Figure 1. Estimated log odds of No judgments across conditions from the model

Yes reading times. Prior to the analysis of "Yes" reading times for targets, data were filtered for outliers in two steps. First, reading times greater than 5,000 milliseconds were omitted because these extreme RTs might have led us to inflated estimation of the data. This affected the removal of 1% data. A linear mixed effect regression was conducted. The same version of the R program was used with the same set of fixed factors being entered in the model in which the factors were coded in the same way as before. The results of our best-fitting model are displayed in Table 3. The correlations of all variables in this model were under .1.

Table 3. Results from the mixed-effect regression on Yes RTs of targets

	Coefficient	S.E.	t-value
Intercept	983.89	49.90	19.72*
Word Order	-152.07 (-75.19)	31.61	-4.81*
Role Shift	169.50 (84.30)	31.08	5.45*
Word Order * Role Shift	-169.86 (-41.77)	62.77	-2.71*

Note. All predictors were centered. Parenthetical values next to the coefficients are standardized coefficients from an alternate version of the model with standardized predictors. If the absolute *t*-value of a fixed factor was over 2, the effect of the factor was considered to be significant at $\alpha < .05$, marked with * (Gelman & Hill, 2007).

The main effect of Word Order was observed, indicating that target words in scrambled sentences took longer to read than those in canonically ordered sentences. Unlike the results from the No judgment model, the main effect of Role Shift appeared, meaning that readers took longer to process the modified head NPs if the thematic roles corresponding to them were required to be shifted. As in the results from the No judgment model, the significant interaction between Role Shift and Word Order emerged (see Figure 2). The nature of the interaction was examined by breaking the data into when sentences were canonically ordered or scrambled. The simple effect of Role Shift occurred significantly when sentences were scrambled (Coefficient = 424.97, S.E. = 80.02, t = 5.31) but marginally significant when sentences were canonically ordered (Coefficient = 88.13, S.E. = 46.56, t = 1.89). In both conditions, comprehenders had more difficulty in the processing of target words when they had to shift the thematic roles corresponding to the head NPs than when they did not have to do so.

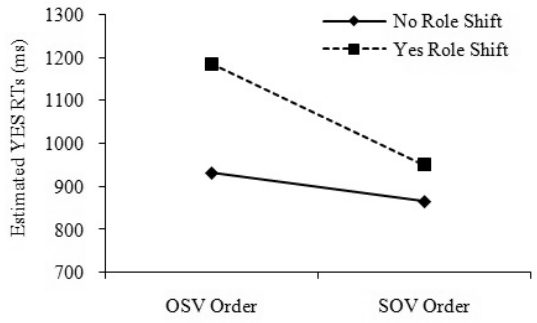


Figure 2. The estimated Yes RTs (*ms*) of targets across conditions

2.3 Discussion

The goal of Experiment 1 was to confirm whether processing difficulty due to role shifting would exist actually. We hypothesized that comprehenders would have difficulty in the processing of head NPs if the roles corresponding to the traces of the NPs need shifting due to the inconsistency to the role information that case markers of the head NPs deliver. We also tested whether the difficulty would be increased if sentences were scrambled.

The results from Experiment 1 supported our hypotheses. First, we found that comprehenders took significantly longer to integrate head NPs into sentences when thematic roles associated with the NPs needed shifting than when they needed not to be shifted. For example, *Haywen-ilul* in *Wupin-ika* | *Kangho-ka* | *pinanha-n* | *Haywen-ilul* | *yongse-hayss-ta* (meaning 'Wupin forgave Haywen who Kangho blamed') was blamed and forgiven as a patient. Comprehenders did not need to revise their representations for the thematic roles associated with *Haywen*, leading to relatively easy integration of *Haywen-ilul* into the sentence. On the contrary, *Haywen-ilul* in *Wupin-ika* | *Kangho-lul* | *pinanha-n* | *Haywen-ilul* | *yongse-hayss-ta* (meaning 'Wupin forgave Haywen who blamed Kangho') blamed Kangho as an agent (although the case marker, *-lul*, were associated with a patient role) but was forgiven by Wupin as a patient. Comprehenders had to reorganize their representations by shifting the thematic roles for *Haywen*, resulting in fairly difficult interpretation of *Haywen-ilul* into the sentence. However, we did not observe the significant effect of role shifting with no judgments. Instead, only numerical differences of No judgments supported our hypothesis. The fact that the significant effect of role shifting emerged only with reading times (but not with judgments) indicated that comprehenders had severe difficulty in reading when they needed shifting thematic roles of the NPs but they did think those sentences were still grammatically sensible.

Second, comprehenders had more difficulty in the processing of scrambled sentences than canonical sentences; they rejected NPs of scrambled sentences more than those of canonical sentences. Also, they took longer to integrate the NPs into scrambled sentences than into canonical sentences. For example, comprehenders felt easier to integrate *Haywen-ilul/ika* into the canonical sentence, *Wupin-ika* | *Kangho-ka* | *pinanha-n* | *Haywen-ilul* | *yongse-hayss-ta* (meaning 'Wupin forgave Haywen who Kangho blamed') than into the scrambled sentence, *Wupin-ilul* | *Kangho-lul* | *pinanha-n* | *Haywen-ika* | *yongse-hayss-ta* (meaning '[Haywen who blamed Kangho] forgave Wupin [ ]'). More difficulty in the processing of scrambled constituents than canonically-ordered constituents suggested that there might need more cognitive efforts from comprehenders in scrambled sentences in computing who-did-what-to-whom argument information, possibly in keeping long distance between scrambled constituents and their traces (Hawkins, 1999; O'Grady, 1997), or, alternatively, in dealing with frequency information such that

canonical-ordered sentences occur more frequently than scrambled sentences (Dryer, 2007). Our result showing comprehenders' heavy cognitive load in the processing of scrambled sentences is consistent to the result found in other studies (Tamaoka, Kanduboda, & Sakai, 2011).

Interestingly, the effect of role shifting, tested on the reading times and the no judgments, was stronger when sentences were scrambled than when sentences were canonically ordered. Presumably, comprehenders went through heavier cognitive loads driven by role shifting in the scrambled sentences than in the canonical sentences. This makes sense given a great amount of information that comprehenders were faced with in order to accommodate their representations with, in particular, when the canonicality of word order was not observed. Comprehenders in the scrambled sentences in which role shifting was required had to bring several processing obstacles, role shifting and scrambling, under control for the integration of target words into sentences. Meanwhile, comprehenders in the canonical sentences in which the roles for targets needed to be shifted had to handle the difficulty due to role shifting only for the integration of target words into sentences.

3. Experiment 2

The purpose of Experiment 2 was to investigate whether the effect of expectation would predict the degree of processing difficulty as the way that the effect of role shifting has shown in Experiment 1. First, we computed probabilistic distributions associated with an upcoming word across conditions. Second, we tested whether our probabilistic measurements significantly predict the degree of processing difficulty.

In order to examine probabilistic distribution corresponding to an upcoming NP, we estimated two types of probabilistic measurements, as graphically illustrated in Figure 3. One was to estimate a target's conditional probability referring to how likely a modified NP that was extracted from an argument position in a fronted relative clause would appear, in comparison to other possible choices. As shown in Figure 3a-b, given the fact that the more frequently mentioned tended to be the more probable, the black piece corresponding to a particular choice (Figure 3b) is considered to be more probable than the black piece corresponding to another particular choice (Figure 3a).

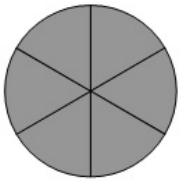
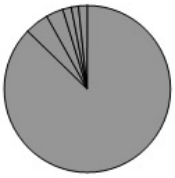
$Conditional\ Probability = P(w_i \mid w_{1\ldots i-1}, \text{CONTEXT})$		$Uncertainty\ (H) = -\sum_{x=i}^{n} P(x) \log_2 P(x)$	
less probable (a)	more probable (b)	more uncertain (c)	less uncertain (d)
			

Figure 3a–d. Graphical examples symbolically illustrate that a whole circle is the collection of all possible choices. Each slice of the circle represents one of the possible choices and its size refers to the likelihood of that particular choice with the bigger being the more probably; a black slice in (3a) referring to less probable word, a black slice in (3b) referring to more probable word, the context (3c) referring to more uncertain context, and the context (3d) referring to less uncertain context.

The other measurement was to estimate the degree of uncertainty referring to how much uncertain it would be to expect what would be coming up next, at the point that a word X occurs. Taking the graphic illustration in Figure (3c-d), the probability distribution of possible choices depicted in Figure 3c indicates that the context is extremely uncertain, in part, because six possible choices are equally likely for a given context and thus it is quite risky to pin down which choice would occur as a target word for an upcoming position. In contrast, the probability distribution of possible choices in Figure 3d where one choice is highly likely than the other choices suggests that the context is fairly certain in that the context provides highly likely information about which choice would appear as a target word at an upcoming position. Unlike the studies that have focused on the reduction of uncertainty under the frame of the entropy-reduction hypothesis, we paid our attention on the degree of uncertainty itself at the position of a target word (c.f., Yun, Mauner, Roland, & Koenig, 2012). We did that because we were more interested in measuring the degree of uncertainty at the very time that a target word occurred rather than the trajectory change of uncertainty as the time course that a series of words were

processed in a sentence. To be brief, in the probabilistic approach, the degree of expectation is high when a target word is highly likely (i.e., high conditional probability) and/or when a context is quite certain (i.e., low uncertainty).

3.1 Obtaining responses

Participants. 48 Konkuk University students attended in this cloze task as a part of class activities.[5]

Materials and Procedures. Participants were given sentence fragments, as shown in (6a)-(6d). They were asked to complete the sentences that were grammatically and semantically correct with whatever came into their minds. All 24 sets of the materials that we used for Experiment 1 were used with 22 filler materials. The fillers were included to block participants from noticing any systematicities.

(6) a. No Role Shift, Not Scrambled:
Wupin-ika | *Kangho-ka* | *pinanha-n* _____
Wupin-NOM Kangho-NOM blame-REL _____
b. Yes Role Shift, Not Scrambled:
Wupin-ika | *Kangho-lul* | *pinanha-n* _____
Wupin-NOM Kangho-ACC blame-REL _____
c. No Role Shift, Scrambled:
Wupin-ilul | *Kangho-lul* | *pinanha-n* _____
Wupin-ACC Kangho-ACC blame-REL _____
d. Yes Role Shift, Scrambled:
Wupin-ilul | *Kangho-ka* | *pinanha-n* _____
Wupin-ACC Kangho-NOM blame-REL _____

3.2 Analysis and results

We collected 2621 responses in total. Out of the responses, we removed 197 completions that were incomplete and ungrammatical. This resulted in omitting 8 % of the data. For the remaining completions, we applied our syntactic criterion for

[5] In this off-line paper-and-pencil task, we did not ask for participant information about gender and age.

them as follows. First, when a completion was a NP attached with a marker that was extracted from an argument position at the fronted clause, it was coded as Relative Noun Clause (RNC). For example, *Wupin-ika Kangho-ka pinan-ha-n chinkwu-lul …* (i.e., Wupin … his friend whom Kangho blamed). Second, when a completion was a NP attached with a marker that was extracted from an adjunct position at the fronted relative clause, it was coded as Relative Adverbial Clause (RAC), as in the example like *Wupin-ika Kangho-lul pinan-h-an pangpepulo Chelho-lul …* (i.e., Wupin …. Chelho in the same way that Wupin blamed Kangho). Third, when a completion was a NP attached with a marker that was modified but not extracted from the fronted relative clause, it was coded as Noun Clause (NC), as in the example of *Wupin-ika Kangho-lul pinan-ha-n sasil…* (i.e., The fact that Wupin blamed Kangho …). Fourth, when a completion was attached with clause markers representing when, because, where, or how, it was coded as a Subordinate Clause (SC) like *Wupini-ka Kangho-lul pinan-ha-n nal-ey …* (i.e., On the day that Wupin blamed Kangho …). Finally, the completions that did not belong to the above four categories were coded as others.

3.2.1 Results from the cloze task

The data from the cloze task was used to constitute the probability distribution of possible continuations. Figure 4a-d display the results in each condition. Overall, participants were more likely to continue the incomplete sentences like (6a-d) into RNC rather than other types of clauses like RAC, NC, or SC. Note that in No Role Shift condition, as illustrated in Figure 4a-b, the probability of the second-likely choice was sharply dropped and other possible choices were very unlikely. Such a predominant preference for RNCs could make comprehenders' expectation on what to encounter highly certain (i.e., low uncertainty). In contrast, in Yes Role Shift condition, as shown in Figure 4c-d, there was no such a dramatic shift from highly likely choices to other possible choices. The probabilities of possible choices were gradually degraded with the number-one choice still being RNCs. The relatively high preference for RNCs might not largely decrease comprehenders' uncertainty for upcoming information (i.e., high uncertainty).

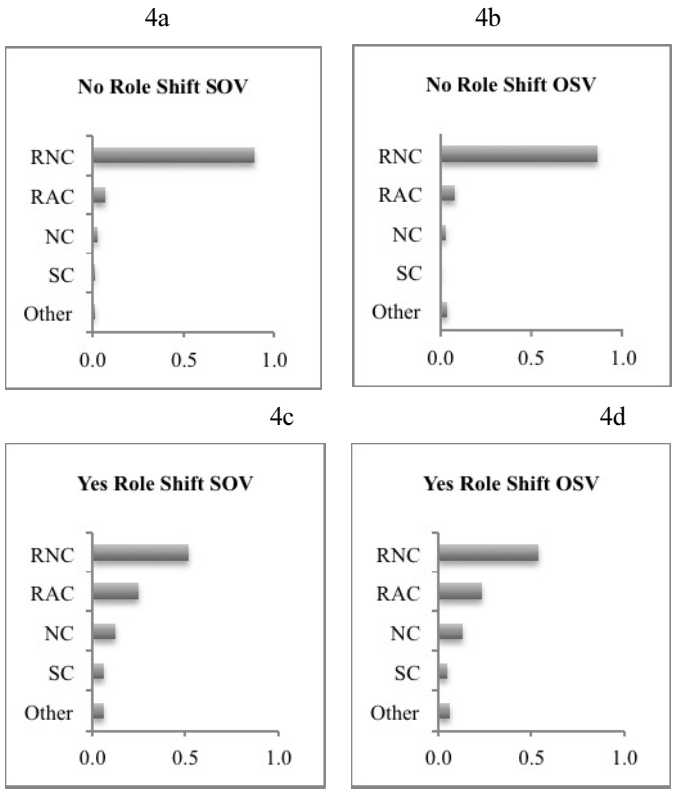


Figure 4a–d. The proportion distributions of each clause in each condition: RNC refers to Relative Noun Clauses; RAC refers to Relative Adverbial Clauses; NC refers to Noun Clauses; SC refers to Subordinate Clause

We tested our probability measurements. First, Figure 5a illustrates proportions of target probability (i.e., RNC completions) across conditions. The likelihood of RNC completions was significantly higher in No Role Shift condition than in Yes Role Shift condition when sentences were canonical (t (23) = 13.87, p < .01) and scrambled (t (23) = 9.56, p < .01). Second, as shown in Figure 5b, the uncertainty of upcoming syntactic information was significantly higher in Yes Role Shift condition than in No Role Shift condition when sentences were canonical (t (23) = -14.41, p < .01) and scrambled (t (23) = -5.39, p <.01). In short, the degree of expectation associated with targets was higher in No Role Shift condition than in Yes Role Shift condition. Comprehenders would feel easier to accommodate their

representations with upcoming information in No Role Shift condition than in Yes Role Shift condition.

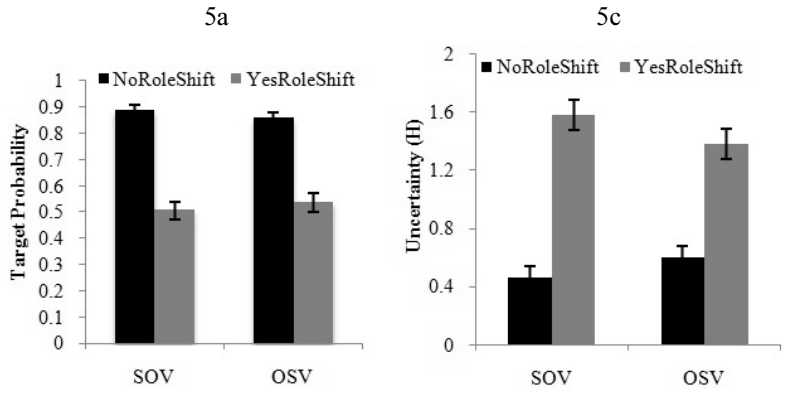


Figure 5a–b. The means of conditional probabilities corresponding to targets (RNCs) in (5a) and the means of uncertainty associated with targets in (5b)

3.2.2 Modeling results

To ensure whether our results in Experiment 1 could also be explained as a function of Expectation, we conducted additional models. The methods and procedures were the same as before. First, as for No judgments, we replaced Role Shift with RNC probability, as in Table 4a, and Uncertainty, as in Table 4b. The significant effect of Word Order remained, but the effect of RNC probability and Uncertainty did not reach to the significant level. The significant interaction between Word Order and Expectation still occurred.

Second, as for Yes reading times, two linear mixed-effect regressions were conducted by using RNC probability, as in Table 5a, and Uncertainty, as in Table 5b. The processing difficulty (i.e., RTs) was significantly reduced as the degree of RNC probability increased and it was inflated as the degree of Uncertainty increased. The effect of Word Order was significant and so was the interaction between Word Order and Expectation.

Table 4a–b. The results of the models analyzing No judgments: RNC probability model in Table 4a and Uncertainty model in Table 4b.

	Coefficient	S.E.	z-score	p-value
a. Using RNC Probability				
Intercept	-5.23	.72	-7.29	.00
Word Order	-4.64 (-2.32)	.46	-10.1	.00
Target Probability	-0.53 (-.12)	.74	-.72	.47
Word Order*Target Probability	5.51 (.64)	1.30	4.25	.00
b. Using Uncertainty				
Intercept	-5.23	.74	-7.13	.00
Word Order	-4.88 (-2.44)	.48	-10.16	.00
Uncertainty	.031 (.019)	.26	.12	.09
Word Order * Uncertainty	-2.09 (-.66)	.49	-4.27	.00

Note. All predictors were centered. Parenthetical values are standardized coefficients with standardized predictors.

Table 5 a–b. The results of the models analyzing Yes RTs of modified head NPs: RNC probability model in Table 5a and Uncertainty model in Table 5b

	Coefficient	S.E.	t-value
a. Using RNC Probability			
Intercept	987.49	51.35	19.23
Word Order	-153.6 (-75.95)	32.01	-4.80
Target Probability	-316.55 (-72.40)	74.81	-4.23
Word Order*Target Probability	-79.63 (-9.01)	141.1	-0.56
b. Using Uncertainty			
Intercept	988.12	52.06	18.98
Word Order	-154.90 (-76.59)	31.86	-4.86 *
Uncertainty	121.7 (77.43)	26.08	4.67 *
Word Order * Uncertainty	-17.83 (-5.61)	51.90	-0.34

Note. All predictors were centered. Parenthetical values are standardized coefficients. The effect of the factor whose absolute *t*-value was above 2 was regarded to be significant at $\alpha < .05$ (Gelman & Hill, 2007).

For further understanding, we illustrated the interaction patterns from all models. Figure 6a-c illustrate the results on No judgments, while Figure 6d-f do them on Yes reading times. The interaction patterns between Word Order and Role Shift (Figure 6a) looked similar with those with RNC probability being used (Figure 6b) and

Uncertainty being used (Figure 6c). Yet, the analyses of Yes reading times showed slightly different patterns across the models. Unlike the model in which Word Order significantly interacted Role Shift (Figure 6d), no significant interactions appeared in the RNC probability model (Figure 6e) and the Uncertainty model (Figure 6f).

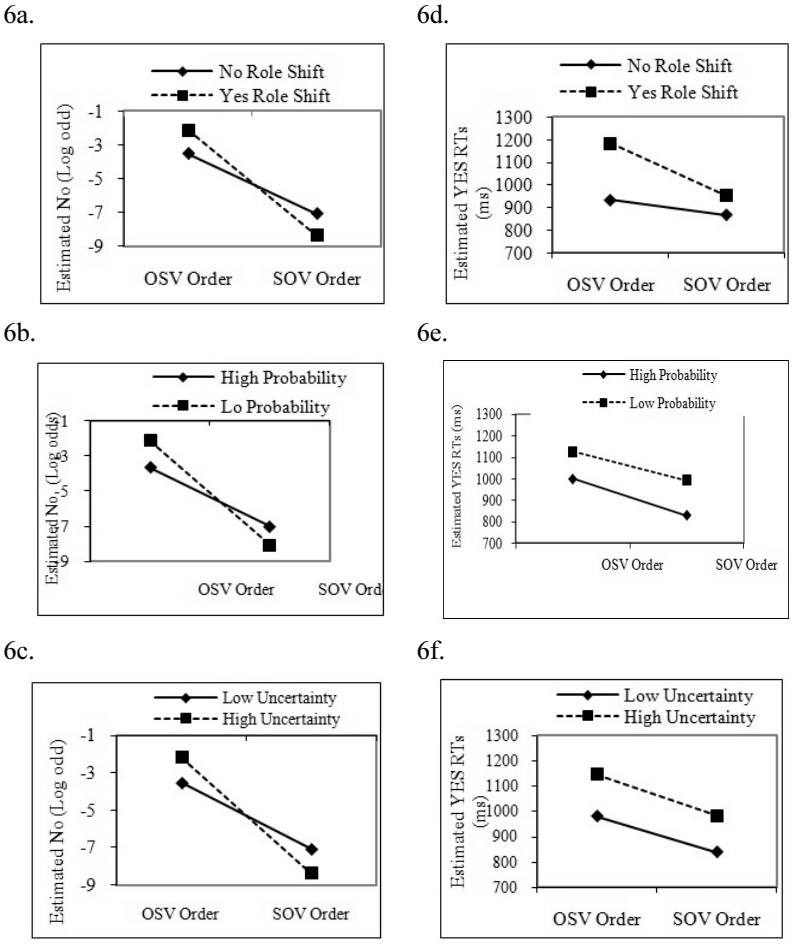


Figure 6a–f. Interactions between Word Order and Role Shift in (6a) and (6d); Interactions between Word Order and Target Probability in (6b) and (6e); Interactions between Word Order and Uncertainty in (6c) and (6f)

Of our great interest, interactions with Word Order found in the each model, as illustrated in Figure 6d-f, suggest that the effect of Expectation might play a

different role in accounting for processing difficulty, relative to that of Role Shift. We further tested the relationship between Role Shift and Expectation as follows.

In order to test whether Expectation play a role as a mediator for Role Shift on Yes reading times, we split the whole data by Word Order and conducted two separate mediation tests, depending on when constituents were canonically arranged (SOV condition) and when constituents were scrambled (OSV condition). To run the mediation test, we followed the procedure proposed by Baron and Kenny (1986). On the one hand, as for the SOV condition, the effect of Role Shift marginally predicted on Yes reading times (Coefficient = 88.13, S.E. = 46.56, t = 1.9) when Role Shift was a single predictor. Role Shift significantly predicted the variance of Expectation; that is, the degree of RNC probability (Coefficient = -.37, S.E. = .01, t = -58.34) and the degree of Uncertainty (Coefficient = 1.11, S.E. = .02, t = 65.61). Importantly, the effect of Role Shift disappeared (Coefficient = -107.46, S.E. = 62.94, t = -1.7) but the effect of Expectation (RNC probability) was still significantly alive (Coefficient = -468.18, S.E. = 153.48, t = -3.05) when both Role Shift and RNC probability were submitted simultaneously in the same model. Similarly, the effect of Role Shift disappeared (Coefficient = -125.72, S.E. = 75.57, t = -1.66) but the effect of Expectation (uncertainty) was still alive (Coefficient = 189.22, S.E. = 60.16, t = 3.15), when Role Shift and Uncertainty were used as predictors simultaneously in the same model. The mediator role of RNC probability on Yes reading times in the SOV condition is illustrated in Figure 7a.

However, we did not find the significant mediator role of Expectation in the OSV condition. Instead, we found that Role Shift mediated the relationship between Expectation and processing difficulty. That is, as for the OSV condition, the degree of RNC probability significantly predicted Yes reading times (Coefficient = -829.87, S.E. = 166.57, t = -4.98) when RNC probability was a single predictor and so did that of Uncertainty (Coefficient = 239.52, S.E. = 57.29, t = 4.18). Role Shift was significantly predicted by the variances of Expectation: both by the degree of RNC probability (Coefficient = -114.91, S.E. = 40.49, z = -2.84, p = .01) and by the degree of Uncertainty (Coefficient = 17.77, S.E. = 3.34, z = 5.33, p = .00). Importantly, when both Role Shift and RNC Probability were used simultaneously in the same model, the effect of Role Shift remained to be significant (Coefficient = 489.9, S.E. = 109.5, t = 4.48) but the effect of Expectation (RNC probability) disappeared (Coefficient = 193.6, S.E. = 230, t = .84). Similarly, when Role Shift

and Uncertainty were used, the effect of Role Shift was significant (Coefficient = 508.2, S.E. = 98.39, t = 5.17) but the effect of Expectation (uncertainty) disappeared (Coefficient = -101.33, S.E. = 71.20, t = -1.42). In contrary to the SOV condition, the effect of Role Shift mediated that of Expectation in the OSV condition (see Figure 7b).

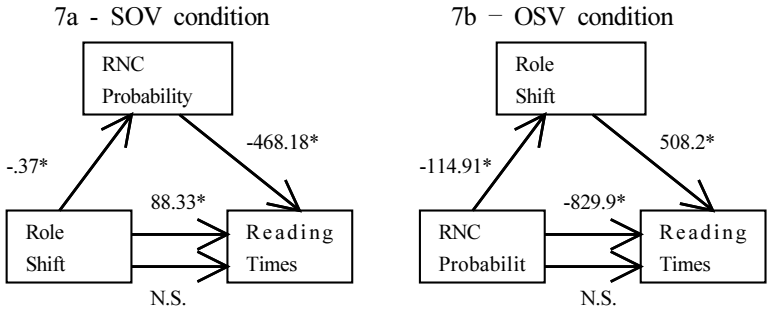


Figure 7a-b. The graphic representation of mediation analyses of Role Shift and Expectation on Yes reading times when constituents were canonically ordered using RNC probability (7a) and when constituents were scrambled using RNC probability (7b). The numbers on the connecting lines between factors represent coefficients of predictors and N.S. refers to be non-significant.

In summary, when constituents were canonically ordered, the effect of Expectation subsumed the effect of Role Shift, revealing the indirect effect of Role Shift and the direct effect of Expectation on the degree of processing difficulty. In contrast, when constituents were scrambled, the effect of Role Shift subsumed the effect of Expectation, revealing the indirect effect of Expectation and the direct effect of Role Shift on the degree of processing difficulty.

3.3 Discussion

The results of Experiment 2 supported our hypotheses. The degree of expectation differed as a function of whether or not the roles associated with head NPs needed shifting. The degree of RNC probability was higher in the context in which role shifting was not necessary than in the context in which role shifting was required.

Also, the degree of uncertainty about what would be coming up for a given context was higher when role shifting was required than when it was not necessary. The results from a series of mixed effect models revealed that Expectation significantly predicted the variances of No judgments and Yes reading times in a similar way that Role Shift did. For example, it was more likely to encounter the extracted head NP, *Haywen-ilul,* given the sentence fragment like *Wupin-ika* | *Kangho-ka* | *pinanha-n* (meaning 'Wupin [Kangho blamed _]$_{REL}$') than the sentence fragment like *Wupin-ika* | *Kangho-lul* | *pinanha-n* (meaning 'Wupin [__ blamed Kangho]$_{REL}$' or '[Wupin blamed Kangho]$_{NOM}$').[6] The higher probability associated with *Haywen* led to an easier integration of the word into the relevant sentence. Or, it was more certain to expect what to come up after the sentence fragment like *Wupin-ika* | *Kangho-ka* | *pinanha-n* (meaning 'Wupin [Kangho blamed _]$_{REL}$') than after the sentence fragment like *Wupin-ika* | *Kangho-lul* | *pinanha-n* (meaning 'Wupin [__ blamed Kangho]$_{REL}$' or '[Wupin blamed Kangho]$_{NOM}$'). The higher certainty (lower uncertainty) at the position that *Haywen* would occur resulted in an easier integration of *Haywen* into the relevant sentence.

Our modeling results of RNC probability on processing difficulty were consistent to what many other studies have demonstrated about the effect of expectation (Boston et al. 2008; Bicknell et al., 2010; Boston et al. 2011; Demberg & Keller, 2008; Hale, 2001; Levy, 2008; Levy et al, 2013; Padó & Crocker, 2009, Roland et al., 2012; Staub, 2010; 2011; Vasishth, 2003). Moreover, we also demonstrated the function of uncertainty on processing difficulty. Instead of using how much the amount of uncertainty is reduced before and after the occurrence of a word in a sentence (Frank, 2010; 2013; Hale, 2003; 2006), we demonstrated that the differences of uncertainty at a particular position across conditions could also explain the differences of processing difficulty. In short, what we observed in the name of expectation was that comprehenders had difficulty in the processing of NPs not only when they did not highly expect to encounter the target NPs but also when they

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6 There might be the third possibility to explain the processing differences between the two types of sentence structures. In the sentence fragment of *Wupin-ika* | *Kangho-lul* | *pinanha-n* (meaning 'Wupin [__ blamed Kangho]$_{REL}$' or '[Wupin blamed Kangho]$_{NOM}$'), the head NP (*Hyewen-ilil*) played a role in resolving garden-path ambiguity in case that comprehenders parsed the previous construction as a noun clause rather than a relative clause. In contrast, there were no concerns on such a garden-path interpretation in the other sentence fragment. We are currently working on this potential issue and thus we will leave it for our current paper.

were quite uncertain about what would be coming up at the position that the target NPs would occur.

To be of our interest, the effect of Expectation differed from that of Role Shift only when the interaction with Word Order was tested on Yes reading times. Unlike the role-shifting model in which the interaction between Role Shift and Word Order was significant, the expectation-based models did not show significant interactions between Expectation and Word Order. The asymmetric patterns of interactions with Word Order across Role Shift and Expectation cued us that the power of Role Shift or Expectation might differ as a function of the canonicality of word order. As we speculated, the results from our mediation analyses revealed that Expectation and Role Shift did not have an equivalent power on determining the degree of processing difficulty. When both Role Shift and Expectation were submitted in the same model, the effect of Expectation subsumed that of Role Shift (c.f., Levy, 2008), only when constituents were canonically arranged. However, when constituents were scrambled, the effect of Expectation disappeared but the effect of Role Shift subsumed that of Expectation. Presumably, the fundamental function of expectation was effective only when the complexity of sentential structures was not substantially severe. We discuss the asymmetric function of expectation in more detail in our general discussion.

Summing up, similar results observed across the expectation-based model and the role-shifting model showed that processing difficulty in reorganizing comprehenders' representations due to role shifting would not be that different, in nature, from the processing difficulty in reorganizing comprehenders' representations that have been constructed by shifting away from expected information to unexpected information. However, different patterns of interactions as a function of Word Order and the results from mediation analyses yielded that the effect of Expectation was not always similar to that of Role Shift.

4. General discussion

We attempted to explore what would underlie the difficulty in the processing of center-embedded relative clauses in Korean. It was hypothesized that the effect of expectation, that of role shifting, or both might attribute to the degree of processing difficulty. To test our hypotheses, we had three goals. Our first goal was to clarify

whether the effect of role shifting would actually exist when we controlled for potential confounding factors that Lee (1996) had. Our second goal was to compute the probabilistic distributions associated with target words across conditions and test the effect of expectation on processing difficulty. We also aimed to compare the results from the expectation-based model to those from the role-shifting model. Our third goal was to explore the relationship between the effect of role shifting and that of expectation. In particular, we planned to test whether the effect of expectation could mediate that of role shifting in predicting the degree of processing difficulty, or *vice-versa*.

We achieved our first goal in Experiment 1. The effect of role shifting was significant on Yes reading times (but not No judgments) when the constituents were canonically arranged, but marginally significant when the constituents were scrambled. Our second goal was accomplished in Experiment 2. The results of the cloze task in Experiment 2 revealed that the extent of expectation to encounter an extracted NP differed as a function of role shifting. Namely, the degree of target probability (i.e., the likelihood that a modified noun that was extracted from an argument position in a relative clause would like to occur) was higher when role shifting was not required than when it was necessary. Also, the degree of uncertainty for upcoming information was higher when role shifting was required than when it was not. The model in which Role Shift was a predictor on No judgments and Yes reading times behaved as similarly as did the models in which Expectation (i.e., target probability or uncertainty) was a predictor on those dependent variables. Interestingly, the results for our third goal revealed that when constituents were canonically arranged, the effect of Expectation subsumed the effect of Role Shift as a mediator, whereas when constituents were scrambled, that of Role Shift subsumed that of Expectation as a mediator. Altogether, our results suggested that the effect of Role Shift is real but not completely independent from that of Expectation.

Expectation as a conditional mediator

Recall the claim of the expectation-based approach (Hale, 2001; Levy, 2008) such that the degree of pre-activation for an upcoming word or phrase determines the degree of processing difficulty for it via the degree of expectation. In particular, Levy (2008) proposed that word's predictability entirely subsumes the activation of other possible sources of information. Thus, it plays a role as a unique predictor like

a perfect mediator on processing difficulty. As Levy (2008) had claimed, we found the effect of expectation (both target probability and uncertainty) as a mediator for that of role shifting in predicting the degree of processing difficulty. However, our results did not fully support Levy's proposal in that expectation as a mediator occurred conditionally as a function of how the constituents were ordered in a sentence. The asymmetrical function of expectation as a mediator depended on the canonicality of word order.

Why did the mediation role of expectation emerge when sentences were canonical but not when sentences were scrambled? We think that the complexity of sentence structures could be a matter. When sentences were severely complicated to process, comprehenders' cognitive resources might be enormously used up to hold the previously provided information and could be busy in integrating incoming information into the existing information. Consequently, comprehenders might not have enough available cognitive resources that they could use anticipatorily the upcoming information that might have been pre-activated from the given context. In this case, the effect of expectation is likely to be weak, although it is still observed at some degree. As for us, at the position that comprehenders encountered the modified NPs, their cognitive load to integrate the incoming NPs into sentences could be much heavier in the scrambled condition than in the canonical condition.

We are in a similar line with other studies suggesting that the function of expectation did not occur as a primary factor in behalf of other factors in comprehending complex sentences. For example, Vasishth, Suckow, Lewis, & Kern (2010) found that in the processing of ungrammatical double-center-embedded relative clauses, there was no effect of expectation in head-initial languages like English. Vasishth et al. (2010) argued that the null effect of expectation was probably due to the fact that comprehenders had to hold a large amount of not-integrated information and thus did not have sufficiently available cognitive resources for expectation. Their claim is supported by Levy et al. (2013) in which the researchers proposed that the role of locality due to working memory was more dominant than the role of expectation in languages like English or Russian. Furthermore, using Hindi, Husain, Vasishth, and Srinivasan (2014) demonstrated that the effect of expectation occurred when the strength of expectation was strong, whereas that of locality (due to the lack of working memory) occurred only when the strength of expectation was weak. Taken together, these previous studies suggest

that the strength of expectation effect is likely to be influenced by the degree to which the complexity of the information that comprehenders have to hold and process. With respects to these studies, our results that expectation played a mediator for role shifting only when sentences were canonically ordered are not surprising. What we have observed, together with the claims proposed by other studies, shows that not only expectation but also other cognitive factors associated with working memory or role shifting should be taken into account in order to increase our understanding for how comprehenders deal with sentence complexity during sentence processing at a fine-grained level.

We have so far discussed that expectation played an important role in the integration of NPs into center-embedded relative clauses. However, we did not explore yet at a deep level why such a probabilistic distribution had to emerge at modified NPs depending on whether or not role shifting was required. This is a topic for our future study exploring what in the previously provided information contributes to generating different degree of expectation for upcoming information.

Remaining question: The interplay between semantic information and syntactic information in the processing of relative clauses

It has been known that subject preferences lead to an easier processing of SRCs than ORCs (Kwon et al., 2010; O'Grady, 1996). However, these preferences for SRCs over ORCs do not always occur. Why? We ask a question about what subject preference means in the processing of relative clauses, especially when sentences are very complex. Our discussion is based on our results and Kwon et al. (2010)'s results.

First, recall our experimental materials like (7a-d). Although we did not intend to manipulate the types of relative clauses, SRCs and ORCs can be found as in (7a) vs. (7b) and in (7c) vs. (7d). Given the comparison of the reading times for head nouns, *Haywen-ilul*, that we observed, we did not find SRC advantages between (7a) and (7b) but found them between (7c) and (7d). The idea of SRC advantages do not provide consistent explanation for our results but the idea of role shifting does. Why did not SRC advantages emerge consistently?

(7) a. No Role Shift, Canonical order, ORC:
Wupin-ika | *Kangho-ka* | *pinanha-n* | *Haywen-ilul* |

Wupin-NOM [Kangho-NOM t_i blame-REL] Haywen$_i$-ACC *yongse-hayss-ta.*
forgave

b. Yes Role Shift, Canonical order, SRC:
Wupin-ika | *Kangho-lul* | *pinanha-n* | *Haywen-ilul* |
Wupin-NOM [t_i Kangho-ACC blame-REL] Haywen$_i$-ACC *yongse-hayss-ta.*
forgave

c. No Role Shift, Scrambled order, SRC:
Wupin-ilul | *Kangho-lul* | *pinanha-n* | *Haywen-ika* |
Wupin-ACC [t_i Kangho-ACC blame-REL] Haywen$_i$ – NOM *yongse-hayss-ta.*
forgave

d. Yes Role Shift, Scrambled order, ORC:
Wupin-ilul | *Kangho-ka* | *pinanha-n* | *Haywen-ika* |
Wupin-ACC [Kangho-NOM t_i blame-REL] Haywen$_i$ -NOM *yongse-hayss-ta*
forgave

Second, recall that in the Kwon et al. (2010)'s study, SRC advantages did not emerge only when relative clauses were center-embedded, as shown in (8a) for SRC and (8b) for ORC. The gaze duration and rereading times for the target head noun, *uywon-ul*, were not different across the conditions. Rather, there were numerical differences of regression-path durations for this constituent but the patterns appeared even oppositely; longer regression path duration in the SRC condition (i.e., 1092 ms) than in the ORC condition (i.e., 1062 ms). Why did not Kwon et al. (2010) observe the processing benefit of SRCs over ORCs in center-embedded relative clauses?

(8) a. Yumyenghan cihwuyca-ka [sengacka-lul chwukcen-ey
famous conductor-NOM [vocalist-ACC festival-to
chotayha-n] **uywon-ul** kongkongyenhi moyokhay-ss-ta
invited-ADN] senator-ACC publicly insult-PST-DECL

b. Yumyenghan cihwuyca-ka [sengacka-ka chwukcen-ey
famous conductor-NOM [vocalist-NOM festival-to

chotayha-n]	**uywon-ul**	kongkongyenhi	moyokhay-ss-ta
invited-ADN]	senator-ACC	publicly	insult-PST-DECL

Notice that in the SRC condition, as in (8a), the roles corresponding to the modified NPs (i.e., *uywon-ul*) needed shifting but in the ORC condition, as in (8b), such a role shifting was not necessary. This suggests that in the processing of sentences like (8a-b), SRC advantages had influences on processing difficulty and role shifting might also play a crucial role. Indeed, the numerical difference of regression path duration for *uywon-ul* between (8a) and (8b) is consistent with our results in a way that role shifting elicited some processing cost to comprehenders.

We think that no benefit of SRCs over ORCs in the Kwon et al.'s study might occur because processing benefits due to SRC advantages might have been cancelled out by the processing cost associated with role shifting. That is, comprehenders might have felt easier to process SRCs than ORCs but the easiness might have been reduced because there was additional processing cost associated with role shifting. Similarly, comprehenders might have some difficulty in the integration of modified nouns into ORCs, but the difficulty might have been somewhat decreased because comprehenders' cognitive effort for role shifting was not additionally needed.

The idea that the effect of role shifting and that of SRC advantages were probably working together can also account for our results. Note that we had marginal effect of role shifting when SRCs require role shifting (i.e., 7a-b), but we had significant effect of role shifting when SRCs do not require role shifting (i.e., 7c-d). As we explained above, our comprehenders might have felt more difficulties in processing sentences that required role shifting than those that do not require role shifting, but the difficulty might have been reduced because there was processing benefits of SRC advantages. Thus, the differences of our reading times across these conditions were reduced a little bit. This might lead to the marginal effect of role shifting in sentences like (7a-b). Contrarily, comprehenders might have more difficulty in the integration of modified nouns into ORCs than SRCs, and the difficulty might have become even more severe because comprehenders' cognitive efforts were additionally needed for role shifting. Thus, the differences of our reading times across these conditions became big. This might lead to the significant effect of role shifting in sentences like (7c-d).

Basically, processing cost associated with role shifting is related to the use of semantic information while processing benefit due to subject preference is rather

related to the use of syntactic information. The possibility that the effect of role shifting and that of SRC advantage have conjoined on processing difficulty provides evidence for the interplay between semantic information and syntactic information in processing. When the syntactic structures of sentences are relatively simple like subject-modifying relative clauses, syntactic advantages might be strong, and thus syntactic advantages on processing difficulty was significant, as found in Kwon et al. (2010). However, when the syntactic structures of sentences are severely complicated like center-embedded relative clauses, syntactic advantages might be weak and play little role on processing difficulty. In these cases, semantic factors seemed to play an important role in affecting the degree of processing difficulty, as found in our study. Furthermore, when the syntactic structures of sentences are even more severely complicated like scrambled center-embedded relative clauses, syntactic advantages might eventually be weaker on processing difficulty. In these cases, semantic factors seemed to play a stronger role in affecting the degree of processing difficulty, as observed in our study.

The asymmetric patterns of our mediation analyses can also reveal the relationship between the syntactic and semantic information on processing difficulty. Recall that our expectation measurements were based on the codes by syntactic categories. In the canonically-ordered sentences where syntactic complexity was relatively tolerable, the effect of Expectation (i.e., syntactic strength) subsumed that of Role Shift on predicting the degree of processing difficulty. In scrambled sentences where syntactic complexity was extremely high, the effect of Expectation disappeared but the effect of Role Shift (semantic strength) subsumed that of Expectation as a mediator on processing difficulty.

Given our speculations above, there seems to be orthogonal-like interplay between semantic and syntactic information. So far, many studies on relative clauses have focused on the use of syntactic information but few studies have tested the role of semantic information. We speculate that the interplay between semantic information and syntactic information might have influences on the degree of processing difficulty in the processing of relative clauses (see similar claims in Tanenhaus & Spivey-Knowlton, 1996; Trueswell, Tanenhaus, & Gransey, 1994). For clear discussion for this matter, we will conduct further studies.

5. Conclusion

We demonstrated the psychological reality associated with role shifting in sentence processing by removing potential confounding factors like scrambling. Using center-embedded relative clauses in Korean, we found that comprehenders had difficulty in the processing of modified head NPs (i.e., long reading times) if the thematic roles associated with them had to be shifted from the thematic roles that were previously assigned within relative clauses. We also demonstrated that the difficulty associated with role shifting was related to how much comprehenders were ready to encounter upcoming information in terms of expectation. Furthermore, we showed that the effect of expectation could mediate the effect of role shifting only when the complexity of sentential structures were not severe but it could not play a role as a mediator when the complexity of structures was severe. Taken together, we claim that the fundamental function of expectation in association with role shifting is effective only when the complexity of sentence structures is not extremely severe.

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