Difficulty of Processing Japanese and Korean Center-embedding Constructions

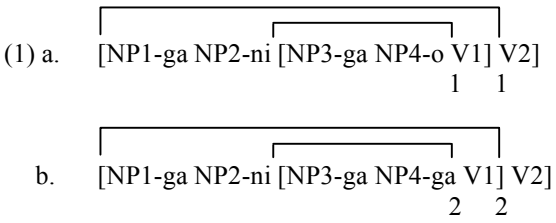
MINEHARU NAKAYAMA, The Ohio State University
SUN-HEE LEE, The Ohio State University
RICHARD L. LEWIS, University of Michigan

Abstract

This research investigates the effects of syntactic, semantic, and morphophonemic similarity in the processing of center-embedding constructions in Japanese and Korean. Six Japanese experiments study the effects of syntactic and semantic similarity, while one Korean experiment deals with the effects of syntactic and morphophonemic similarity. The results from these experiments support the view that the difficulty of processing center-embeddings is in part explained by similarity-based interference in working memory.

1. Introduction

It has been argued that the difficulty of processing center-embedding is in part explained by similarity-based interference in working memory (Lewis, 1996). Lewis (1998) posited a metric that predicts processing load based on the combined effects of retroactive and proactive interference on syntactic attachments. For instance, when the subject is attached to the first embedded verb (V1) in (1a), the item to be retrieved is the third noun phrase, marked with nominative *-ga* (NP3-*ga*). The set of items potentially contributing interference retroactively is only NP4-*o*, but since it is accusative marked and cannot appear in subject position, it causes minimal interference. The set of items potentially contributing interference proactively includes NP1-*ga*, and NP2-*ni*, but only NP1-*ga* contributes significant interference, because its nominative marking indicates that it is a potential subject. The subject attachment of V2 is similar to this: retrieving NP1-*ga* suffers little proactive interference, but is retroactively interfered with by NP3-*ga*. Thus, in both cases, there is one unit of interference for the subject attachments (indicated by the 1 below each verb).



Structure (1b) is similar to (1a), but the embedded clause is now a double nominative construction with a stative verb V1 taking a *-ga* marked subject and a *-ga* marked object. The potential subjecthood of NP4-*ga* increases the retroactive interference for the subject attachments of both V1 and V2. Therefore, V1 suffers from one unit of retroactive interference and one unit of proactive (total two), and V2 suffers from two units of retroactive interference (total two). In this way, the theory accounts for the difficulty of (1b) in contrast to (1a).

Lewis and Nakayama (1999, 2001, 2002) found sentence type (2a) to be more difficult than (2b). Since (2a) contains two *-ga* marked NPs (i.e., V1 suffers from one unit of proactive interference), while (2b) has only one, the former is more difficult than the latter. This is explained by the similarity-based interference theory. Furthermore, it was found that (2d) is more difficult than (2c). This is because two *-ga* marked NPs are adjacent in (2d), while they are not in (2c). Two items with the same grammatical functions must be distinguished based on serial position, and are therefore subject to positional confusion, which is maximized when they are adjacent.

(2) a. [NP1-*ga* [NP3-*ga* NP4-*o* V1] V2]
b. [NP1-*wa* [NP3-*ga* NP4-*o* V1] V2]
c. [NP1-*ga* NP2-*ni* [NP3-*ga* NP4-*o* V1] V2]
d. [NP1-*ga* [NP3-*ga* NP2-*ni* NP4-*o* V1] V2]

Since the previous research focused on the effects of syntactic similarity, the present paper reports the effects of semantic and morphophonemic similarity.

2. Semantic Similarity

2.1 *Experiments 1 and 2*

Experiments 1-2 tested the effects of semantic discriminability of stacked NPs. Experiment 1 was a paper-and-pencil questionnaire study, where 60 participants from a Japanese university were asked to rate the difficulty of a sentence on a seven point scale (7=very difficult to understand). Experiment 2 employed the same test material as in Experiment 1, but was a non-cumulative moving window study implemented in Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Macintosh Powerbook G3. Thirty participants from another university participated in Experiment 2. In addition to reading, these participants were asked to rate the difficulty of each sentence on a seven point scale as in Experiment 1. They read the sentences one word (or *bunsetsu,* i.e., NP-*ga/o/ni*) at a time by pressing the space bar. Each time the subject hit the space bar, the next word was uncovered on the screen and the previous word was hidden with a string of dashes. At the end of the sentence there was a period, and as soon

as the participant hit the space bar, the period disappeared and the screen presented the instruction to rate the difficulty of the sentence just read. Then, the subject typed in a number from one to seven.

The sentence types in (3) illustrate two types of matrix verbs, transitive and ditransitive (i.e., with or without two consecutive subject NPs), and three mixes of animacy (i.e., four, three, or two animate nouns). Of these, the sentence types with all animate NPs were used in Lewis and Nakayama (1999, 2001, 2002). All nouns and verbs were controlled in terms of their familiarity ratings. The number of mora and letters was not controlled. Appropriate characters (i.e., *hiragana*, *katakana*, and *kanji*) were used in order to avoid reading difficulties. Each sentence type had four sentence tokens among 56 filler sentences (i.e., total 80 sentences).[1]

(3)a. [Animate NP-*ga* Ani NP-*ni* [Ani NP-*ga* Ani NP-*o* V-*to*] V]
Kyoju-ga shacho-ni daihyo-ga kokosei-o shinsasuru-to yakusokushita.
'The professor promised the president that the representative would examine high school students.'

b. [Animate NP-*ga* Ani NP-*ni* [Ani NP-*ga* Inanimate NP-*o* V-*to*] V]
Ani-ga sensei-ni onna-no-ko-ga basu-o untensuru-to renrakushita.
'The elder brother informed the teacher that a girl is going to drive a bus.'

c. [Animate NP-*ga* Inanimate NP-*ni* [Ani NP-*ga* Inani NP-*o* V-*to*] V]
Kacho-ga kaisha-ni hitobito-ga hoteru-o yoyakushita to hokokushita.
'The section chief reported to the company that people made their own reservations at the hotel.'

d. [Animate NP-*ga* [Ani NP-*ga* Ani NP-*ni* Ani NP-*o* V-to] V]
Otoko-no-ko-ga hahaoya-ga isha-ni akachan-o miseta-to omoidashita.
'The boy remembered that the mother showed a baby to the doctor.'

e. [Animate NP-*ga* [Ani NP-*ga* Inanimate NP-*ni* Ani NP-*o* V-*to*] V]
Haisha-ga tsuyaku-ga daitoryo-ni nihongo-o oshieru-to oboeteita.
'The dentist remembered that the interpreter would teach Japanese to President.'

[1] An anonymous SLS reviewer pointed out that there were possible contextual, semantic and pragmatic factors affecting the test sentences. For instance, *daihyo* 'representative' requires a specificity that must be retrieved from the context. We realize this kind of possible contextual influence, but we leave the issue for the future research.

f. [Animate NP-*ga* [Ani NP-*ga* Inanimate NP-*ni* Inani NP-*o* V-*to*] V]
Bengoshi-ga shain-ga apato-ni shinbun-o kubaru-to kimeta.
'The lawyer decided that an employee would deliver the newspaper to the apartment.'

The following table shows the average ratings of the six sentence types.

Table1. Average Ratings of the Six Sentence Types

	Non-consecutive Subjects		Consecutive Subjects	
	Questionnaire	MW	Questionnaire	MW
4 Animate NPs	4.22	4.23	5.3	4.38
3 Animate NPs	4.28	3.68	5.1	4.62
2 Animate NPs	4.87	4.08	5.05	4.10

(7=very difficult to understand; MW: Moving-window study)

A statistical tool, Analysis of Variance (ANOVA), was employed. The results indicate that there was a significant animacy effect by subject analysis, but not by item analysis in Experiment 1 ($F1(2,58)=4.25$, $p=0.016$, $F2(2,18)=0.60$, $p=0.557$) and there were no significant animacy effects in both subject and item analyses in Experiment 2 ($F1(2,28)=1.61$, $p=0.209$; $F2(2,18)=0.62$, $p=0.552$). However, the sentences without consecutive subject NPs (i.e., ditransitive sentences) were significantly easier to understand than the those with consecutive subjects (Ex 1 $F1(1,59)=47.41$, $p=0.000$, $F2(1,18)=10.86$, $p=0.004$; Ex 2 $F1(1,29)=9.61$, $p=0.004$; $F2(1,18)=4.94$, $p=0.039$). The latter finding is the same as in Lewis and Nakayama (1999, 2001, 2002). There was a significant interaction of animacy and the consecutive subject NPs in subject analyses, but not in item analyses (Ex 1 $F1(2,118)=14.81$, $p=0.000$, $F2(2,18)=1.57$, $p=0.235$; Ex 2 $F1(2,58)=6.26$, $p=0.003$, $F2(2,18)=3.00$, $p=0.075$). The lack of a significant effect of semantic (animacy) similarity was rather unexpected, given the fact that some studies such as Inoue and Den (1997) report animacy effects.[2] In our materials, however, the animacy manipulation was masked by the different syntactic constructions (i.e., NPs were already syntactically distinct). Therefore, it might be the case that making the two syntactically indiscriminable NPs (i.e., *ga*-NPs) semantically more distinct could help processing. We tested this possibility in Experiments 3-6.

[2] Inoue and Den's study was on garden-path (relative clause) constructions. Their findings revealed that the animacy of the object NP affected the relative clause reading, but not the animacy of the subject NP. In our study, we manipulated the animacy of the subject and the indirect object NPs.

2.1. *Experiments 3 - 6*

All the critical sentences in Experiments 3-5 had two NPs in which the first NP was always an animate (human) NP, and the second NP varied in animacy. Again all nouns and verbs were controlled in terms of their familiarity ratings. All embedded verbs were neutral verbs that can take either animate or inanimate subjects. In Experiments 3-4, the matrix NP was a familiar Japanese family name and had either a topic or a nominative marker. The second NP was a common noun and always had a nominative marker. Test sentence types from the three experiments are listed in (4). In Experiment 3, the embedded verb was active intransitive (i.e., (4a) and (4b)), whereas it was passive transitive (i.e., (4c) and (4d)) in Experiment 4. Experiment 5 included (4b) and (4d) double *-ga* sentences in order to uncover any intransitive/transitive differences. Each sentence type had four sentence tokens among 34 fillers (Latin Square). The three experiments employed a magnitude estimation moving window task in order to avoid issues (e.g., an ordinal scale problem) discussed in Bard, Robertson, and Sorace (1996). Three 40 native speaker groups from three different universities participated in the experiments. Table 2 shows the average log-converted scores by sentence type (a higher number means a sentence type is more difficult to understand).

(4)a. [Animate NP-*wa* [Ani NP/Inanimate NP-*ga* V-*to*] V]
Yamaguchi-wa gakusei-ga/okane-ga nokotteiru-to yososhita.
'Yamaguchi predicted students/money would remain.'

b. [Animate NP-*ga* [Ani NP/Inanimate NP-*ga* V-*to*] V]
Yamaguchi-ga gakusei-ga/okane-ga nokotteiru-to yososhita.
'Yamaguchi predicted students/money would remain.'

c. [Animate NP-*wa* [Ani NP/Inanimate NP-*ga* Vpassive-*to*] V]
Yamaguchi-wa gakusei-ga/okane-ga nokosareteiru-to yososhita.
'Yamaguchi predicted students/money would be left.'

d. [Animate NP-*ga* [Ani NP/Inanimate NP-*ga* Vpassive-*to*] V]
Yamaguchi-ga gakusei-ga/okane-ga nokosareteiru-to yososhita.
'Yamaguchi predicted students/money would be left.'

Table 2. Average Scores of the Six Sentence Types

	(4a)NP1-*wa* (4b)NP1-*ga*		(4c)NP1-*wa* (4d)NP1-*ga*		(4b) Intrans. (4d) Passive	
Animate	.760	.923	.851	.985	.871	.898
Inanimate	.719	.888	.838	.971	.839	.891

Again, ANOVA was used to analyze the data. The results of Experiments 3 and 4 indicate a significant difference between the *wa* and *ga*-sentence types (Ex 3 F1(1,39)=83.5, p=0.0001, F2(3,60)=39.089, p=0.0001; Ex 4 F1(1,39)=58.489, p=0.0001, F2(3,60)=24.446, p=0.0001). Experiment 5 shows a significant difference in verb types in the subject analysis, but not in the item analysis (i.e., active intransitive vs. passive transitive) (F1(3,39)=9.298, p=0.004, F2(3,60)=2.494, p=0.120). [3] Experiments 3 and 5 demonstrate significant differences in animacy in the subject analyses, but not in the item analyses (Ex 3 F1(1,39)=13.877, p=0.001, F2(3,60)=2.201, p=0.143; Ex 5 F1(3,39)=4.696, p=0.036, F2(3,60)=0.492, p=0.486) and no significant differences in animacy were found in both subject and item analyses in Experiment 4 (F1(1,39)=1.016, p=0.320, F2(3,60)=0.209, p=0.649). The null results in animacy may be because the experiments employed an end-of-sentence magnitude estimation task and the embedded verbs could take both animate and inanimate subjects. Therefore, we looked into the on-line reading times in another experiment.

Experiment 6 contained the same test and filler sentences as in Experiment 3, but the test sentences were embedded in another clause to prevent the reading times of the first NP and the last verb from being masked by sentence initial and end of sentence wrap-up effects.[4] The experiment employed a comprehension task: half of both test and filler sentences had yes-no questions. Forty-four Japanese native speakers from a university participated in the experiment. Figure 1 shows the residual reading time of each position for the animate-animate and animate-inanimate sentence types. The vertical lines indicate the standard error bars. Those with two animate NPs were slower at V1 and V2 than those with

[3] This means the intransitive vs. passive difference did not affect the sentence difficulty as much as the *wa* vs. *ga* difference. However, this may be because all sentences were short. Had the sentences been longer or more complex, the verb type difference might have been significant.

[4] Note that the reading times obtained in Experiments 3-5 were not usable for analyses because of the sentence initial and end of sentence wrap-up effects. Therefore, Experiment 6 was necessary.

animate and inanimate NPs, but this is not conclusive as differences were not statistically significant at all positions.

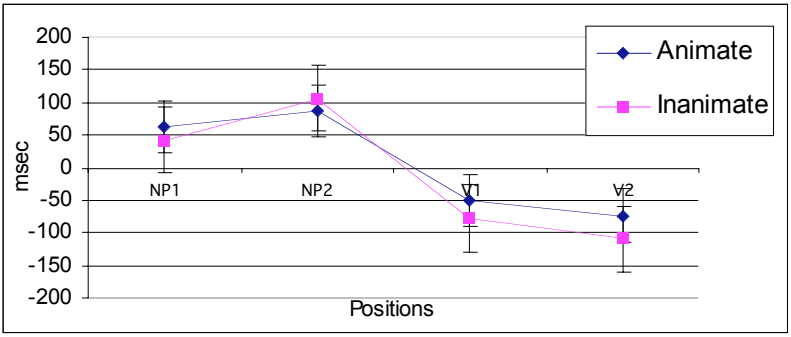


Figure 1. Average Residual Times by Position for Sentences with Animate and Inanimate NP2

Figure 2 exhibits the residual reading time of each position for the *wa-ga* and *ga-ga* sentence types. The double *ga* nominative sentences took more time at the second *-ga* marked NP as well as at the two verb positions. The slowdown at the second *-ga* marked NP position may come from the fact that the two syntactically similar NPs appear consecutively. However, again, these are not conclusive as differences were not statistically significant.

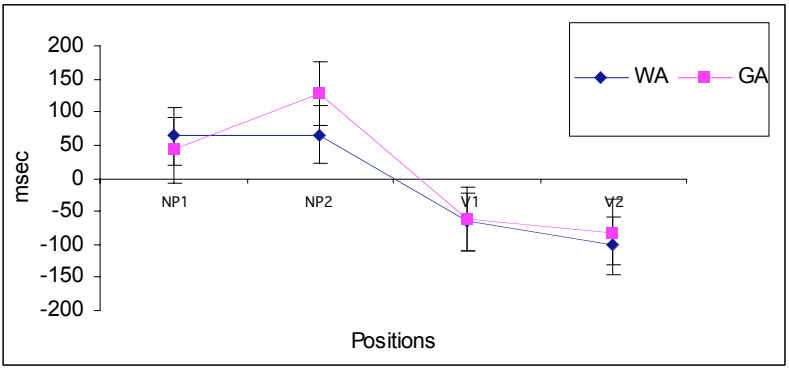


Figure 2. Average Residual Times for *WA* vs. *GA* Sentences

Thus far, increasing semantic discriminability appears to have relatively little effect compared to syntactic discriminability. This may be because of the influence of syntactic discriminability and the use of neutral verbs. That

is to say, syntactic discriminability is robust and its presence had already minimized semantic discriminability. Moreover, it is important to remember that no test sentence violated selectional restrictions though animacy was varied (i.e., no verbs that do not take inanimate nouns were used). When we conducted an additional questionnaire study on the selectional restriction violation employing similar sentences to those in Experiment 3 above, there was indeed a significant effect of the animacy violations ($F1(1,43)=37.445$, $p=0.0001$; $F2(1,30)=16.091$, $p=0.0001$). The fact that the verbs used in Experiments 3-6 were all neutral with respect to animacy (i.e., no selectional restriction violations) may have further minimized the perceptual difficulty.

3. Morphophonemic Similarity

The final experiment investigates the effect of morphophonemic similarity (see also Lee and Nakayama 2003). Based upon Uehara and Bradley's (1996) finding, Lewis and Nakayama (2002) conclude that the processing difficulty of *ga-ga* sentences like (2a) compared to *wa-ga* sentences like (2b) is due to the effects of syntactic similarity. However, Vasishth (2002) presents evidence for the effects of morphophonemic similarity in Hindi. Therefore, the processing difficulty of *ga-ga* sentences may be due to the morphophonemic similarity. Morphophonemic effects cannot be tested in Japanese because there are no multiple morphophonemic representations for one single grammatical function (though the reverse case - one morphophonemic representation for multiple grammatical functions - exists). However, Korean is a language which is structurally similar to Japanese, but different in that it has two morphophonemically distinct nominative case markers, *-ka* and *-i*. Nouns ending in vowels take *-ka* as a nominative case marker while nouns ending in consonants take *-i*. The processing difficulty of the six sentence types in (5) was tested by using a magnitude estimation moving window task on an Macintosh iBook. Each test sentence contained three two-syllable nouns (i.e., two characters) and two verbs. NP1 and NP2 were proper nouns. NP3 was a common noun. All nouns and verbs were controlled in terms of their familiarity ratings. NP1 had three types of markers: topic *-num*, nominative *-ka*, and nominative *-i*. NP2 had two variations of nominative case markers: *–ka* and *-i* (3 x 2 design). The familiarity of the nouns and the plausibility of the test sentences were all controlled (based on data collected from a different group of participants). Each sentence type had four sentence tokens among 56 fillers (Latin Square). Forty-eight Korean native speakers (ages 19-36, mean=28.2) at an American university (lengths of US stay 0;2-4;8, mean=2.04) participated in the study. The log-converted average difficulty ratings of the six sentence types are stated in Table 3 (a higher number = more difficult to understand).

(5)a [NP1-*nun* [NP2-*ka* NP3-*lul* V] V]
Euncwu-nun Yengay-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay had visited the professor.'

b. [NP1-*nun* [NP2-*i* NP3-*lul* V] V]
Euncwu-nun Hisen-i kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Hisen had visited the professor.'

c. [NP1-*ka* [NP2-*ka* NP3-*lul* V] V]
Euncwu-ka Yengay-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay had visited the professor.'

d. [NP1-*ka* [NP2-*i* NP3-*lul* V] V]
Euncwu-ka Hisen-i kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Hisen had visited the professor.'

e. [NP1-*i* [NP2-*ka* NP3-*lul* V] V]
Hisen-i Euncwu-ka kyoswu-lul chacawassta-ko kiekhayssta.
'Hisen remembered that Encwu had visited the professor.'

f. [NP1-*i* [NP2-*i* NP3-*lul* V] V]
Hisen-I Swuceng-i kyoswu-lul chacawassta-ko kiekhayssta.
'Hisen remembered that Swuceng had visited the professor.'

Table 3. Average Ratings of the Six Sentence Types

	NP1-*nun*	NP1-*ka*	NP1-*i*
NP2-*ka*	.562	.769	.701
NP2-*i*	.608	.723	.755

ANOVA revealed that the topic *–nun* sentences were significantly easier than the nominative *–ka/i* sentences (F1 (1,47)=33.209, p=0.0001; F2 (1,46)=38.285, p=0.001). This finding is the same for Japanese (Experiments 3 and 4 above and Lewis and Nakayama 1999, 2001, 2002). The finding is consistent with accounts put forth by Babyonyshev and Gibson (1999), Gibson (2000), Uehara and Bradley (2002), and Vasishth (2002). Furthermore, the topic sentences with *nun-ka/nun-i* were also found to be significantly easier than the nominative sentences with *ka-i/i-ka* (F1 (1,47)=34.481, p=0.0001; F2 (1,46)=45.736, p=0.0001). This means that the topic sentences were much easier among the sentences with the morphophonemically dissimilar markers, suggesting effects of both structural/syntactic and phonological/morphophonemic similarity. This is

consistent with the "feature bundles" approach in Lewis (2002) and Vasishth (2002), which appeal to similarity-based interference in working memory. See also Gordon, Hendrick, and Johnson (2001) and Gordon, Hendrick, and Levine (2002) among others.

Among the nominative sentences, the same nominative sequences (*ka-ka* and *i-i*) were significantly different from dissimilar sequences ($F1(1, 47)=14.259$, $p=0.0001$; $F2(1,46)=4.554$, $p=0.038$). This shows the effects of phonological/morphophonemic similarity, which is consistent with the findings in Vasishth (2002). This result cannot be explained by the theories presented in Babyonyshev and Gibson (1999) and Gibson (2000). It is also different from Uehara and Bradley's (1996) finding, whose study did not include topic sentences. The present experiment and theirs are different in that the test sentences in our study include topic sentences and have only a single embedding with a mix of proper and common nouns, whose number of syllables and familiarity are controlled. Their study might have obtained null results because of the complexity of the constructions, i.e., structurally their sentences were too difficult.

The results of Experiment 7 indicate that similarity effects are at work morphophonemically as well. This suggests that the difficulty of two nominative NPs in Japanese, e.g., (2a), is due to the effects of both morphophonemic and syntactic similarity interference.

4. Conclusion

The present results from Japanese and Korean experiments are consistent with the similarity-based hypothesis that making the NPs more distinct morphophonemically, semantically, or syntactically makes processing easier, but the degree of the effect depends on whether or not the features are relevant to determining the interpretation. Features that are relevant have a large effect (e.g., case markings that indicate syntactic positions of NPs), but features that are not relevant have a small effect (e.g., animacy when selectional restriction is satisfied). We leave the precise calculation of these different effects in a computational model for future research. However, it is worth pointing out that the current results would bring a challenge to theories that take the sole linguistic approach to explain the difficulty of processing certain constructions (e.g., Babyonyshev & Gibson 1999 and Gibson 2000).

Finally, it is also important to point out that we have not considered discourse effects in the interpretation of the results above. If there were any discourse factors that made topic sentences easier, we have not seen effects of syntactic similarity interference. Therefore, discourse effects must be clarified in future research as well.

Acknowledgements

We would like to thank two SLS anonymous reviewers, Hidetoshi Sirai, Allison Blodgett and Laurie Maynell for their useful comments on the earlier version of this paper; Noriko Yoshimura, Yuki Hirose, and Keiko Uehara for their assistance in collecting data; and Koichi Sawasaki for his assistance in statistical analyses. Part of this research was supported by a targeted interdisciplinary seed grant by The OSU Office of Research and Graduate Studies to the first and third authors.

References

Babyonyshev, M. & Gibson, E. (1999). The complexity of nested structures in Japanese. *Language, 75(3)*, 423-450.

Bard, E. G., Robertson, D. & Sorace, A. (1996). Magnitude estimation of linguistic acceptability. *Language, 72(1)*, 32-68.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments & Computers 25 (2)*, 257-271.

Gibson, E. (2000). Dependency locality theory: A distance-based theory of linguistic complexity. In A. Marantz, Y. Miyashita, and W. O'Neil (eds.), *Image, Language, Brain: Papers from the first mind articulation project symposium*. Cambridge: MIT Press.

Gordon, P., Hendrick, C. & Johnson, M. (2001). Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory & Cognition, 27.6*, 1411-1423.

Gordon, P., Hendrick, C. & Levine, W. H. (2002) Memory-load interference in syntactic processing. *Psychological Science, 13(5)*, 425-430.

Inoue, M. & Den, Y. (1997). Meishi-no yusei-sei-ga nihongo garden path gensho-ni oyobosu eikyo. [Effects of animacy in Japanese garden path pehonmena]. Paper presented at the 14th Japan Cognitive Science Society.

Lee, S.-H., & Nakayama, M. (2003). Effects of syntactic and phonological similarity in Korean center-embedding constructions. Paper presented at the 16th annual CUNY Conference on Human Sentence Processing. (See http://tedlab.mit.edu/CUNY2003/viewAbstract.php?abstract=204)

Lewis, R. L. (1996). Interference in short-term memory: The magical number two (or three) in Sentence Processing. *Journal of Psycholinguistic Research 25(1)*, 93-115. (See also http://www-personal.umich.edu/~rickl/ papers.html)

Lewis, R. L. (1998). Interference in working memory: Retroactive and proactive interference in parsing. Paper presented at the 11th annual CUNY Human Sentence Processing Conference. (http://www-personal. umich.edu/~rickl/presentations.html)

Lewis, R. L. & Nakayama, M. (1999). Determinants of processing complexity in Japanese embeddings: New theory and data. Paper presented at the International East Asian Psycholinguistics Workshop. The Ohio State University.

Lewis, R. L. & Nakayama, M. (2001). The representation of serial order information in sentence processing: Insights from work on short term memory and implications for processing complexity. Paper presented at the 14th annual CUNY Human Sentence Processing Conference. (http://www-personal.umich.edu/~rickl/presentations.html)

Lewis, R. L. & Nakayama, M. (2002). Syntactic similarity effects of embeddings in Japanese. In M. Nakayama (ed.), *Sentence Processing in East Asian Languages*. 85-110. Stanford: CSLI. (See also http:// www-personal.umich.edu/~rickl/papers.html)

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994) Semantic influences on parsing: use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language 33*, 285-318.

Uehara, K. & Bradley, D. (1996). The effect of -ga sequences on processing Japanese multiply center-embedded sentences, in Byung-Soo Park and John-Bok Kim, eds., *Language, Information and Computation*. Seoul: Kyung Hee University.

Vasishth, S. (2002) Working memory in sentence comprehension: Processing Hindi center-embeddings. Doctoral dissertation. The Ohio State University.

Appendix Test sentences

Experiments 1 and 2

a. [Animate NP-ga Ani NP-ni [Ani NP-ga Ani NP-o V-to] V]

Kyoju-ga shacho-ni daihyo-ga kokosei-o shinsasuru-to yakusokushita.
'The professor promised the president that the representative would examine high school students.'

Anaunsa-ga jumin-ni keikan-ga daigakusei-o shirabeta-to hososhita.
'The announcer broadcasted to the citizens that the policeman investigated the college student.'

Ryoshin-ga hitobito-ni puro-ga satsujinhan-o sagasu-to happyoshita.
'The parents publicly announced to the people that the professional would look for the murderer.'

Chugakusei-ga OL-*ni seijika-ga ototo-o tsukatta-to itta*.
'The junior high school student told the female office worker that the politician used his brother.'

b. [Animate NP-ga Ani NP-ni [Ani NP-ga Inanimate NP-o V-to] V]

Ani-ga sensei-ni onna-no-ko-ga basu-o untensuru-to renrakushita.

'The elder brother informed the teacher that a girl is going to drive a bus.'

Suponsa-ga tsuma-ni otosan-ga jisho-o tsukutta-to kotaeta.

'The sponsor answered my wife that his father made a dictionary

Tencho-ga senpai-ni kyaku-ga ocha-o nomu-to tsutaeta.

'The branch manager informed his senior that the guest would drink tea.'

Josei-ga itoko-ni musukosan-ga terebi-o naoshita-to iihatta.

'The woman insisted to my cousin that her son repaired the TV.'

c. [Animate NP-ga Inanimate NP-ni [Ani NP-ga Inani NP-o V-to] V]

Kacho-ga kaisha-ni hitobito-ga hoteru-o yoyakushita to hokokushita.

'The section chief reported to the company that people made their own reservations at the hotel.'

Okusan-ga toshokan-ni otto-ga hon-o yomu-to henjishita.

'The wife responded to the library that her husband would read the book.'

Shogakusei-ga gakko-ni oya-ga shosetsu-o kaita-to shiraseta.

'The grade school student informed his school that his parents wrote a novel.'

Bijinesuman-ga daigaku-ni musume-ga yasai-o taberu-to chuishita.

'The businessman cautioned the university that his daughter eats vegetables.'

d. [Animate NP-ga [Ani NP-ga Ani NP-ni Ani NP-o V-to] V]

Otoko-no-ko-ga hahaoya-ga isha-ni akachan-o miseta-to omoidashita.

'The boy remembered that the mother showed a baby to the doctor.'

Ashisutanto-ga kakari-ga hannin-ni kodomo-o watasu-to shitteita.

'The assistant knew that the person in charge would hand over the child to the criminal.'

Keisatsukan-ga gakusei-ga yujin-ni imoto-o uru-to kangaeta.

'The policeman thought that the student would sell his sister to his friend.'

Seito-ga koshi-ga repota-ni sakka-o shokaishita-to kizuita.

'The student noticed that the lecturer introduced the author to the reporter.'

e. [Animate NP-ga [Ani NP-ga Inanimate NP-ni Ani NP-o V-to] V]

Haisha-ga tsuyaku-ga daitoryo-ni nihongo-o oshieru-to oboeteita.

'The dentist remembered that the interpreter would teach Japanese to President.'

Tomodachi-ga ojosan-ga dansei-ni hana-o ageta-to kanashinda.

'The friend lamented that the daughter (of someone he knows) gave flowers to the man.'

Suta-ga kyokan-ga untenshu-ni zasshi-o okuru-to shinjiteita.

'The star believed that the teacher would send a magazine to the driver.'

Kantoku-ga piccha-ga kanai-ni kuruma-o hakonda-to nayandeita.

'The manager was annoyed by the fact that the pitcher delivered a car to his wife.'

f. [Animate NP-ga [Ani NP-ga Inanimate NP-ni Inani NP-o V-to] V]

Bengoshi-ga shain-ga apato-ni shinbun-o kubaru-to kimeta.

'The lawyer decided that an employee would deliver the newspaper to the apartment.'

Haha-ga chichi-ga gomibako-ni wain-o nageru-to kanjita.

'The mother sensed that the father would throw the wine into the trash box.'

Jokyoju-ga shijo-ga ginko-ni okane-o haratta-to kokaishita.

'The assistant professor regretted that the children paid money to the bank.'

Serusuman-ga bucho-ga mise-ni tegami-o teishutsushita-to omotta.

'The sales person thought that the department head submitted the letter to the shop.'

Experiments 3 and 6

[Animate NP-wa/ga [Ani NP/Inanimate NP-ga V-to] V]

Takahashi-wa/ga daigakusei/kuruna-ga hashiru-to rikaishiteiru.

'Takahashi understands that the college student/car will run.'

Hashimoto-wa/ga shain/shijo-ga sodatta-to kanshinshita.

'Hashimoto was impressed by the fact that the employees/market grew.'

Sakamoto-wa/ga jimusho/keikan-ga utsutta-to omoidashita.

'Sakamoto remembered the policeman/office moved.'

Nakamura-wa/ga kyoju/hana-ga mitsukatta-to kirokushita.

'Nakamura recorded that the professor/flower was found.'

Watanabe-wa/ga isha/basu-ga tomatta-to handanshita.

'Watanabe recognized the doctor/bus stopped.'

Matsumoto-wa/ga oya/ginko-ga tasukatta-to kanjita.

'Matsumoto felt that the parents/bank was saved.'

Saito-wa/ga daitoryo/ie-ga taoreta-to omoikonda.

'Saito believed that President/the house fell.'

Nakajima-wa/ga sensei/amerika-ga katta-to kizuita.

'Nakajima noticed the teacher/America won.'

Ishikawa-wa/ga shacho/maketto-ga kimatta-to kangaeta.

'Ishikawa thought that the company president was decided/market was settled'

Yamaguchi-wa/ga gakusei/okane-ga nokotteiru-to yososhita.

'Yamaguchi predicted that the student/money would remain.'

Yamamoto-wa/ga seito/tokei-ga ugoiteita-to oboeteiru.

'Yamamoto remembered that the student/clock was moving.'

Inoue-wa/ga kodomo/mise-ga dokuritsusuru-to kanashinda.

'Inoue was sad about the child/store is becoming independnet.'

Yamashita-wa/ga kyaku/kasa-ga tatteita-to hihanshita.

'Yamashita criticized that the guest/umbrella was standing.'

Yamazaki-wa/ga tomodachi/kaisha-ga kawatta-to shinjiteita.

'Yamazaki believed that the friend/company changed.'

Murakami-wa/ga shogakusei/densha-ga okureta-to kokaishiteita.

'Murakami was regretting that the grade school child/train was late.'

Kondo-wa/ga piccha/omocha-ga atsumatta-to omotta.

'Kondo thought the pitchers/toys gathered.'

Experiment 4

[Animate NP-wa/ga [Ani NP/Inanimate NP-ga Vpassive-to] V]

Yamaguchi-wa/ga gakusei-ga/okane-ga nokosareteiru-to yososhita.

'Yamaguchi predicted students/money would be left.'

Takahashi-wa/ga daigakusei/kuruma-ga hashirasareru-to rikaishiteiru.

'Takahashi understands that the college student/car will be made to run.'

Hashimoto-wa/ga shain/shijo-ga sodaterareta-to kanshinshita.

'Hashimoto was impressed by the fact that the employees/market was grown.'

Sakamoto-wa/ga keikan/jimusho-ga utsusareta-to omoidashita.

'Sakamoto remembered the policeman/office was moved.'

Nakamura-wa/ga kyoju/hana-ga mitsukerareta-to kirokushita.

'Nakamura recorded that the professor/flower was found.'

Watanabe-wa/ga isha/basu-ga tomerareta-to handanshita.

'Watanabe recognized the doctor/bus was stopped.'

Matsumoto-wa/ga oya/ginko-ga tasukerareta-to kanjita.

'Matsumoto felt that the parents/bank was saved.'

Saito-ga daitoryo/ie-ga taosareta-to omoikonda.

'Saito believed that President/the house was fallen.'

Nakajima-wa/ga sensei/amerika-ga katasareta-to kizuita.

'Nakajima noticed the teacher/America was led to win.'

Ishikawa-wa/ga shacho/maketto-ga kimerareta-to kangaeta.

'Ishikawa thought that the company president was decided/market was settled.'

Yamaguchi-wa/ga gakusei/okane-ga nokosareteiru-to yososhita.

'Yamaguchi predicted that the student/money would be left.'
Yamamoto-wa/ga seito/tokei-ga ugokasareteita-to oboeteiru.
'Yamamoto remembered that the student/clock was moved.'
Inoue-wa/ga kodomo/mise-ga dokuritsusareru-to kanashinda.
'Inoue was sad about the child/store became independnet.
Yamashita-wa/ga kyaku/kasa-ga tatasareteita-to hihanshita.
'Yamashita criticized that the guest/umbrella was made to stand.'
Yamazaki-wa/ga tomodachi/kaisha-ga kaerareta-to shinjiteita.
'Yamazaki believed that the friend/company was changed.'
Murakami-wa/ga shogakusei/densha-ga okurasareta-to kokaishiteita.
'Murakami was regretting that the grade school child/train was made to be late.'
Kondo-wa/ga piccha/omocha-ga atsumerareta-to omotta.
'Kondo thought the pitchers/toys were gathered.'

Experiment 5 Sentences with NP-ga in Experiments 3 and 4

Experiment 7
a. [NP1-nun [NP2-ka/i NP3-lul V] V]
Euncwu-nun Yengay-ka/Hisen-i kyoswu-lul chacawassta-ko kiekhayssta.
'Encwu remembered that Yengay/Hisen had visited the professor.'
Sangwu-nun Yengco-ka/Minchel-i phansa-lul hyeppakhayssta-ko kkwumyessta.
'Sangwu fabricated that Yengco/Minchel threatened the judge.'
Eunhye-nun Yumi-ka/Misen-i cakka-lul chwicayhayssta-ko ohayhayssta.
'Eunhye misunderstood that Yumi/Misen interviewed the writer.'
Congswu-nun Yengkyu-ka/Changlyel-i senswu-lul kyelcenghayssta-ko cimcakhayssta.
'Congswu guessed that Yengkye/Changlyel decided players.'
Hyencwu-nun Eunmi-ka/Miyen-i paywu-lul kyengmyelhayssta-ko poassta.
'Hyencwu considered that Eunmi/Miyen looked down on actors. '
Minkyu-nun Cinwu-ka/Caymin-i kisa-lul pyenhohayssta-ko uysimhayssta.
'Minkyu doubted if Cinwu/Caymin defended the driver.'
Cenga-nun Yenhi-ka/Hyeceng-i swunye-lul silhehayssta-ko mitessta.
'Cenga believed that Yenghi/Hyeceng hated the nun.'
Hyoli-nun Eunha-ka/Kyengsen-i cwupwu-lul moyokhayssta-ko nukkyessta
'Hyoli felt that Eunha/Kyengsen insulted a housewife.'
Chanho-nun Hyenwu-ka/Yengcwun-i kyengpi-lul pwullewassta-ko sangsanghayssta.
'Chanho imagined that Hyenwu/Yengcwun called a guard.'
Sungcay-nun Inho-ka/Cengwuk-i uysa-lul cimanghayssta-ko chakkakhayssta.
'Sungcay mistook that Inho/Cengwuk wished to become a doctor.'
Hicwu-nun Swunca-ka/Swukkyeng-i yaksa-lul twulyewehayssta-ko myosahayssta.
'Hicwu described that Swunca/Swukkyeng was afraid of the pharmacist.'

Kyengthay-nun Senwu-ka/Minsek-i nongpwu-lul milessta-ko hwaksinhayssta.
'Kyengthay convinced that Senwu/Minsek pushed the farmer.'
Cengay-nun Kyuli-ka/Yengsil-i moksa-lul conkyenghayssta-ko phantanhayssta.
'Cengay concluded that Kyuli/Yengsil respected the pastor'
Kithay-nun Congho-ka/Cengil-i kangsa-lul kwuthahayssta-ko kiswulhayssta.
'Kithay stated that Congho/Cengil beat the instructor.'
Sena-nun Hyenmi-ka/Hyecin-i kaswu-lul tongkyenghayssta-ko hyosanghayssta.
'Sena recalled that Hyenmi/Hyecin adored a singer.'
Chelswu-nun Sangho-ka/Tonghyen-i swuwi-lul ttaylyessta-ko tancenghayssta.
'Chelswu concluded that Sangho/Tonghyen hit the janitor.'
Kyengswu-nun Sengcay-ka/Cenghwan-i kyosa-lul myentamhayssta-ko yesanghayssta.
'Kyengswu expected that Sengcay/Cenghwan met the teacher.'
Cenghwa-nun Minci-ka/Pokyeng-i kemsa-lul pinanhayssta-ko incenghayssta.
'Cenghwa admitted that Minci/Pokyeng blamed the prosecutor.'
Seyho-nun Myengwu-ka/Yongsik-i pise-lul iyonghayssta-ko chwuchukhayssta.
'Seyho conjectured that Myengwu/Yongsik took advantage of the secretary.'
Hyeli-nun Yenswu-ka/Cengok-i mokswu-lul ttalakassta-ko sayngkakhyassta.
'Hyeli thought that Yenswu/Cengok followed the carpenter.'
Inswu-nun Hicay-ka/Caypem-i hakca-lul intepyuhayssta-ko hwakinhayssta.
'Inswu confirmed that Hicay/Caypem interviewed a scholar.'
Yengwu-nun Cini-ka/Swupin-i hwanca-lul kanhohayssta-ko chwucenghayssta.
'Yengwu presumed that Cini/Swupin attended a patient.'
Cenghye-nun Mina-ka/Nayeng-i hwaka-lul swungpayhayssta-ko phyohyenhayssta.
'Cenghye expressed that Mina/Nayeng adored the patient.'
Swunca-nun Yengchay-ka/Yengin-i kica-lul onghohayssta-ko oinhayssta
'Swunca misunderstood that Yengchay/Yengin supported the reporter.'

b. [NP1-ka [NP2-ka/i NP3-lul V] V]
Euncwu-ka Yengay-ka/Hisen-i kyoswu-lul chacawassta-ko kiekhayssta.`
'Encwu remembered that Yengay/Hisen had visited the professor.'
Sangwu-ka Yengco-ka/Minchel-i phansa-lul hyeppakhayssta-ko kkwumyessta.
'Sangwu fabricated that Yengco/Minchel threatened the judge.'
Eunhye-ka Yumi-ka/Misen-i cakka-lul chwicayhayssta-ko ohayhayssta.
'Eunhye misunderstood that Yumi/Misen interviewed the writer.'
Congswu-ka Yengkyu-ka/Changlyel-i senswu-lul kyelcenghayssta-ko cimcakhayssta.
'Congswu guessed that Yengkyu/Changlyel decided players.'
Hyencwu-ka Eunmi-ka/Miyen-i paywu-lul kyengmyelhayssta-ko poassta.
'Hyencwu considered that Eunmi/Miyen-i looked down on actors. '
Minkyu-ka Cinwu-ka/Caymin-i kisa-lul pyenhohayssta-ko uysimhayssta.
'Minkyu doubted if Cinwu/Caymin defended the driver.'
Cenga-ka Yenhi-ka/Hyeceng-i swunye-lul silhehayssta-ko mitessta.
'Cenga believed that Yenghi/Hyeceng hated the nun.'

Hyoli-ka Eunha-ka/Kyengsen-i cwupwu-lul moyokhayssta-ko nukkyessta.
'Hyoli felt that Eunha/Kyengsen insulted a housewife.'
Chanho-ka Hyenwu-ka/Yengcwun-i kyengpi-lul pwullewassta-ko sangsanghayssta.
'Chanho imagined that Hyenwu/Yengcwun called a guard.'
Sungcay-ka Inho-ka/Cengwuk-i uysa-lul cimanghayssta-ko chakkakhayssta.
'Sungcay mistook that Inho/Cengwuk wished to become a doctor.'
Hicwu-ka Swunca-ka/Swukkyeng-i yaksa-lul twulyewehayssta-ko myosahayssta.
'Hicwu described that Swunca/Swukkyeng was afraid of the pharmacist.'
Kyengthay-ka Senwu-ka/Minsek-i nongpwu-lul milessta-ko hwaksinhayssta.
'Kyengthay convinced that Senwu/Minsek pushed the farmer.'
Cengay-ka Kyuli-ka/Yengsil-i moksa-lul conkyenghayssta-ko phantanhayssta.
'Cengay concluded that Kyuli/Yengsil respected the pastor.'
Kithay-ka Congho-ka/Cengil-i kangsa-lul kwuthahayssta-ko kiswulhayssta.
'Kithay stated that Congho beat the instructor.'
Sena-ka Hyenmi-ka/Hyecin-i kaswu-lul tongkyenghayssta-ko hyosanghayssta.
'Sena recalled that Hyenmi/Hyecin adored a singer.'
Chelswu-ka Sangho-ka/Tonghyen-i swuwi-lul ttaylyessta-ko tancenghayssta.
'Chelswu concluded that Sangho/Tonghyen hit the janitor.'
Kyengswu-ka Sengcay-ka/Cenghwan-i kyosa-lul myentamhayssta-koyesanghayssta.
'Kyengswu expected that Sengcay/Cenghwan met the teacher.'
Cenghwa-ka Minci-ka/Pokyeng-i kemsa-lul pinanhayssta-ko incenghayssta.
'Cenghwa admitted that Minci/Pokyeng blamed the prosecutor.'
Seyho-ka Myengwu-ka/Yongsik-i pise-lul iyonghayssta-ko chwuchukhayssta.
'Seyho conjectured that Myengwu/Yongsik took advantage of the secretary.'
Hyeli-ka Yenswu-ka/Cengok-i mokswu-lul ttalakassta-ko sayngkakhyassta.
'Hyeli thought that Yenswu/Cengok followed the carpenter.'
Inswu-ka Hicay-ka/Caypem-i hakca-lul intepyuhayssta-kohwakinhayssta.
'Inswu confirmed that Hicay/Caypem interviewed a scholar.'
Yengwu-ka Cini-ka/Swupin-I hwanca-lul kanhohayssta-ko chwucenghayssta.
'Yengwu presumed that Cini/Swupin attended a patient.'
Cenghye-ka Mina-ka/Nayeng-i hwaka-lul swungpayhayssta-ko phyohyenhayssta.
'Cenghye expressed that Mina/Nayeng adored the patient.'
Swunca-ka Yengchay-ka/Yengin-i kica-lul onghohayssta-ko oinhayssta.
'Swunca misunderstood that Yengchay/Yengin supported the reporter.'

c. [NP1-i [NP2-ka/i NP3-lul V] V]
Hisen-i Euncwu-ka/Swuceng-i kyoswu-lul chacawassta-ko kiekhayssta.
'Hisen remembered that Euncwu/Swuceng visited the professor.'
Minchel-i Sangwu-ka/Caywuk-i phansa-lul hyeppakhayssta-ko kkwumyessta.
'Mincel fabricated that Sangwu/Caywuk threatened the judge.'
Misen-i Eunhye-ka/Hyeceng-i cakka-lul chwicayhayssta-ko ohayhayssta.

'Misen misunderstood that Eunhye/Hyeceng interviewed the writer.'

Changlyel-i Congswu-ka/Insek-i senswu-lul kyelcenghayssta-ko cimcakhayssta.

'Changlyel guessed that Chongswu/Insek decided players.'

Miyen-i Hyencwu-ka/Hyelim-i paywu-lul kyengmyelhayssta-ko poassta.

'Miyen considered that Hyencwu/Hyelim looked down on actors.'

Caymin-I Minkyu-ka/Yenghwun-i kisa-lul pyenhohayssta-ko uysimhayssta.

'Caymin doubted if Minkyu/Yenghwun defended the driver.'

Hyeceng-i Cenga-ka/Eunswuk-i swunye-lul silhehayssta-ko mitessta.

'Hyeceng believed that Cenga/Eunswuk-i hated the nun.'

Kyengsen-i Hyoli-ka/Hoceng-i cwupwu-lul moyokhayssta-ko nukkyessta.

'Kyensen felt that Hyoli/Hoceng insulted a housewife.'

Yengcwun-i Chanho-ka/Tonghwun-i kyengpi-lul pwullewassta-ko sangsanghayssta.

'Yengcwun imagined that Chanho/Tonghwun called a guard.'

Cengwuk-i Sungcay-ka/Sungyun-i uysa-lul cimanghayssta-ko chakkakhayssta.

'Cengwuk mistook that Sungcay/Sungyun wished to become a doctor.'

Swukkeng-i Hicwu-ka/Yenswuk-i yaksa-lul twulyewehayssta-ko myosahayssta.

'Swukkeng described that Hicwu/Yenswuk was afraid of the pharmacist.'

Minsek-I Kengthay-ka/Hichel-i nongpwu-lul milessta-ko hwaksinhayssta.

'Minsek convinced that Kengthay/Hichel pushed the farmer.'

Yengsil-I Cengay-ka/Ciyun-i moksa-lul conkyenghayssta-ko phantanhayssta.

'Yengsil concluded that Cengay/Ciyun-i respected the pastor.'

Cengil-i Kithay-ka/Kyenghwan-i kangsa-lul kwuthahayssta-ko kiswulhayssta.

'Cengil stated that Kithay/Kyenghwan beat the instructor.'

Hyecin-i Sena-ka/Inswuk-i kaswu-lul tongkyenghayssta-ko hyosanghayssta.

'Hyecin recalled that Sena/Inswuk adored a singer.'

Tonghyen-i Chelswu-ka/Kyengsek-i swuwi-lul ttaylyessta-ko tancenghaystta.

'Tonghyen concluded that Chelswu/Kyengsek hit the janitor.'

Cenghwan-i Keyngswu-ka/Sunghyen-i kyosa-lul myentamhayssta-ko yesanghayssta.

'Cenghwan expected that Kyengswu/Sunghyen met the teacher.'

Pokyeng-i Cenghwa-ka/Hiswuk-i kemsa-lul pinanhayssta-ko incenghayssta.

'Pokyeng admitted that Cenghwa/Hiswuk-i blamed the prosecutor.'

Yongsik-i Seyho-ka/Yengkil-i pise-lul iyonghayssta-ko chwuchukhayssta.

'Yongsik conjectured that Seyho/Yengkil took advantage of the secretary.'

Cengok-I Heyli-ka/Yewen-i mokswu-lul ttalakassta-ko sayngkakhayssta.

'Cengok thought that Hyeli/Yewen followed the carpenter.'

Caypem-i Inswu-ka/Kwangsep-i hakca-lul intepyuhayssta-ko hwakinhayssta.

'Caypem confirmed that Inswu/Kwangsep interviewed a scholar.'

Swupin-i Yengwu-ka/Okkyeng-i hwanca-lul kanhohayssta-ko chwucenghayssta.

'Swupin presumed that Yengwu/Okkyeng attended a patient.'

Nayeng-I Cenghye-ka/Miran-i hwaka-lul swungpayhayssta-ko phyohyenhayssta.

'Nayeng expressed that Cenghye/Miran adored the patient.'

Yengin-i Swunca-ka/Senhyeng-i kica-lul onghohayssta-ko oinhayssta.
'Swunca misunderstood that Swunca/Senhyeng supported the reporter.'