Reanalysis Costs in Processing Japanese Sentences with Complex NP Structures and Homonyms: Individual Differences and Verbal Working Memory Constraints

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Reanalysis Costs in Processing Japanese Sentences with Complex NP Structures and Homonyms: Individual Differences and Verbal Working Memory Constraints

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This paper examines the function of a syntactic constraint in real-time sentence processing and the reanalysis costs in Japanese sentences including complex NP structures or homonyms with the special concern to individual differences of verbal working memory constraints. Two self-paced reading experiments were carried out. Their results indicate that a syntactic constraint requiring adequate dependency relations between a predicate and its argument(s) is operating in real time, and that a reanalysis associated with a greater structural change is more costly. Our results also reveal that individuals who get high scores in the Japanese Reading Span Test interpret sentences with costly reanalyses more accurately but spend longer time than those with low scores. Some theoretical implications of our results to parsing principles and working memory models are discussed. We also touch on the functional significance of the limitation of working memory.
Key Words: Japanese sentence processing; reanalysis cost; verbal working memory; Japanese Reading Span Test; local syntactic ambiguity; homonym

A reanalysis can cause difficulty in human sentence processing. Sentences with severe processing difficulty putatively caused by reanalysis are garden path (GP) sentences as in (1).

(1) a. The horse raced past the barn fell. (Bever, 1970)

b. Yoko-ga kodomo-o koosaten-de mikaketa
name$_f$-NOM child-ACC intersection-LOC saw
takusii-ni noseta.
taxi-DAT put on
'Yoko made the child ride the taxi she saw at the intersection.' (Mazuka & Itoh, 1995)

It is not the case, however, that every reanalysis is associated with GP effect. Many researchers have discussed the structural properties to distinguish reanalyses that cause GP effect from those that do not. In most of these discussions, the judgment of GP effect is binary, but recent researches have revealed that GP effect is graded (Fodor & Ferreira, 1998). The cost of a reanalysis thus should be quantitatively specified to construct a cognitively more plausible model of human sentence processing. The first objective of this paper is to experimentally express the exact degree of processing difficulty caused by a reanalysis in Japanese sentences.

Syntactic knowledge is generally assumed to be homogeneous among native speakers. The basic presupposition of syntactic research is that all native speakers coincide in the grammatical judgment of a given string. It is often the case, however, that researchers disagree on this judgment. Individual differences in real-time language use are further noticeable. In the tradition of syntactic theory, these individual differences are regarded as noise irrelevant to the structure of knowledge of language. To construct a syntactic theory valid in real-time sentence processing, however, these differences are desirable to be systematically explained. As the second objective of this paper, we try to attribute the individual differences in sentence processing to verbal working memory constraints. Experiment 1 discusses the reanalysis in complex NP structures, and Experiment 2 that in homonyms.

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Experiment 1

Method

Participants. Eighty-eight students of Shigakukan University participated in the study for payment. They were native speakers of Japanese. They took part in the Japanese Reading Span Test (Osaka, 1998). In this test, the participants read a set of unrelated sentences aloud on a computer screen without pausing between sentences. At the end of a set, they were asked to recall all target words underlined in red in the sentences in the set. They were instructed not to offer first the target word in the last sentence of a set. The participants were initially given five sets with two sentences per set. If they correctly recalled the two target words for at least one of the five sets, they were presented with five three-sentence sets, followed by five four- and five five-sentence sets. The test was discontinued at a set of given size when a participant failed to correctly recall the target words for all the sets. A weighted items span (WIS) was calculated

for each participant to quantitatively estimate the individual difference of verbal working memory constraints (Rosen & Engle, 1998; May, Hasher, & Kane, 1999; Chiappe, Hasher, & Siegel, 2000). The WIS can range from 0 to 70. The mean WIS of the participants was 12.12 (SD=7.38). The participants who scored over/under the mean with more than a half of SD were grouped as High Span Group (HSG, seventeen participants) and Low Span Group (LSG, twenty-eight) respectively. The residual forty-three are Medium Span Group (MSG).

Stimuli. Three types of Japanese sentences with complex NP structure were examined as control and experimental sentences.

(2) a. Control sentence (Control)

P(hrase)1	P2	P3
Taro-ga	shoogakusei-o	ijimeta
name$_m$-NOM	primary school child-ACC	bullied

P4	P5	P6	P7
jijitsu-ni	sobo-ga	rippukushita	.
fact-DAT	grandmother-NOM	got angry	

'My grandmother got angry at the fact that Taro had bullied a primary school child.'

b. Early boundary sentence (EB)

P1	P2	P3	P4
Hanako-ga	saihu-o	otoshita	koohai-ni
name$_f$-NOM	wallet-ACC	lost	junior-DAT

P5	P6	P7
okane-o	kashita	.
money-ACC	lent	

'Hanako lent some money to her junior who had lost his/her wallet.'

c. Late boundary sentence (LB)

P1	P2	P3	P4
Taro-ga	terebi-o	shuurishita	jitensha-ni
name$_f$-NOM	the TV-ACC	repaired	bicycle-DAT

P5	P6	P7
shizukani	noseta	.
softly	loaded	

'Taro loaded the TV softly on the bicycle he had repaired.'

A sentence of each type was spaced out into six phrases and an end-point (*maru*). All P1s are NPs with their heads as common Japanese first or family names nominatively marked by *ga*. All P2s are NPs accusatively marked by *o*. All P3s are verbs in past tense that can select the P1s and P2s as their subjects and objects respectively. All P4s are NPs datively marked by *ni*. P4s in EB have human nouns as their heads. The head nouns of P4s in LB are inanimate.[1] In Control, P1, P2 and P3 construct a complement clause for the noun in P4. P2 and P3 in EB and P3 in LB construct a relative clause with its head as the noun in P4. P5s in Control are *ga*-marked human NPs, which are matrix subjects. P5s in EB are *o*-marked NPs, which are the accusative objects of the main verbs. In LB P5s are adverbial phrases modifying the main verbs. All P6s are main verbs in past tense. All words were chosen from a standard Japanese dictionary for primary school children, and their frequencies were controlled for phrase positions by *Asahi* Newspaper Digital Archives. The stimulus sentences were written in the standard Japanese orthography, namely, Chinese characters and two syllabaries (*hiragana* and *katakana*).[2] Thirty sentences with ten for each type were included in the main session.[3] The other thirty were included in the main session as fillers. Ten of them were simple sentences, and the other twenty were complex sentences without complex NP structure.

Procedure. The experiment was conducted on a Power Macintosh 7300 running SuperLab (Cedrus Corporation) with a Response Box RB-400 (Cedrus Corporation). Sentences were presented on a computer screen by a phrase-by-phrase, self-paced, non-cumulative reading paradigm. The presentation point was fixed to be vertically centered and horizontally leftmost on the screen. Each trial began with a prompt to indicate the beginning of a sentence. After the end point of a sentence, a Yes/No question examining the comprehension of the thematic relation in the sentence was presented. The participants were instructed to respond to a question by pressing one of the two buttons (Yes or No). The question for (2b), for example, is "The person who lost the wallet is the junior. Yes or No?" (the correct answer in this case is "Yes"). The questions are designed to choose one of the two relevant alternatives, namely in this case, *Hanako* and *koohai* (junior). Two kinds of audio responses corresponding to the answers (correct or incorrect) were given to the participants as feedback. The order of presentation of the stimulus sentences was randomized for each participant. The practice session included four trials. The experiment took participants approximately twenty minutes.

Predictions

Dependency relations between lexical items in a Japanese sentence cannot be determined before the end of the sentence because of its head-final nature. It is widely accepted, however, that human sentence processing is incremental, and it is costly to retain input items unstructured. It is reasonable to assume, therefore, that a clausal structure is constructed at the input of P3 with its predicate as P3 and its subject and object as P1 and P2 respectively. When a complex NP structure is recognized at P4, the clausal structure from P1 to P3 is maintained in Control while the subject of P3 must be reanalyzed from P1 to P4 in EB. Also in LB, P4 turns out to be

[1] Gunji (1987) analyses phrases marked by case particles like P1, P2 and P4 as postpositional phrases with their heads as postpositions (case particles). Our analysis does not depend on a specific syntactic analysis as far as P1 and P2 are guaranteed to be possible arguments of P3.

[2] *Hiragana* is one of the two syllabaries in Japanese. The other is *katakana*, which is usually used for foreign words.

[3] For the details of the experimental sentences, consult Appendix A.

the accusative object of P3, and P2 must be reanalyzed to be a non-clause mate of P3. This reanalysis of P2 necessitates another reanalysis of P1. Mazuka and Itoh (1995) pointed out that a reanalysis had a psychologically measurable cost and multiple reanalyses could be increasingly costly. The reanalysis of P1 and P2 (subject and object) in LB is thus predicted to be more costly than that of P1 (subject) in EB. Here we should note the experimental findings of Hirose and Inoue (1998) that the thematic ambiguity of the head noun in Japanese relative clause structure aggravated the processing difficulty associated with subject (and object) reanalysis. We thus semantically and pragmatically controlled EB so that P4 might not be interpreted as the dative object of P3 at P4: In (2b), for example, '*Hanako lost her wallet for her junior.' In the same way, LB was controlled so that the instrumental interpretations of P4 might not be possible: In (2c), for example, '*Taro repaired the TV by a bicycle.' Since a reanalysis is predicted at P4 in EB and LB and the reanalysis in the latter will be more costly, the reading times (RTs) at P4 and the error rates in comprehension questions should be graded as follows:

(3) Prediction 1: Reanalysis cost
RT at P4 and error rate in comprehension question: Control $<$ EB $<$ LB

The Reading Span Test is closely related with language comprehension ability. King and Just (1991) reported that in their RT experiment for sentences involving costly object relative clauses as in (4a) and those with less costly subject relatives as in (4b), readers who got high scores in the English Reading Span Test by Daneman and Carpenter (1980) (high-span readers) had better comprehension rates than those with low scores (low-span readers), especially for object relatives. Further, the mean RT of high-span readers at *admitted* in (4a) was significantly shorter than that of low-span readers.

(4) a. Object relative
The reporter that the senator attacked admitted the error publicly after the hearing.

b. Subject relative
The reporter that attacked the senator admitted the error publicly after the hearing.

They claim that the poor performance of low-span readers, especially on the more computationally demanding object relatives, is due to their lack of working memory capacity. A high score in the Reading Span Test is generally understood as a manifestation of language processing efficiency. Miyake, Just, and Carpenter (1994) reported that lexical ambiguity as in *boxer* in (5) affected the processing of low-span readers more deeply than that of high-span readers. That is, low-span readers spent relatively longer time than (M)/LSG from the processing point of *pet store* to the final word, and their comprehension accuracy was worse than the other two groups.

(5) Since Ken really liked the boxer, he took a bus to the nearest pet store to buy the animal.

They claim that high-span readers can simultaneously maintain the subordinate interpretation of *boxer* (a short-haired dog) in addition to the dominant (a pugilist) while low-span readers retain only the dominant because of the lack of working memory capacity. Therefore, when the subordinate interpretation is required at *pet store* (and later), this interpretation is not easily available for low-span readers. This is assumed to be the reason for the response pattern. (e.g., Daneman and Carpenter (1980), Masson and Miller (1983) and Miyake et al. (1994) for English, and Osaka and Osaka (1994) for Japanese)

One of the most frequently discussed situations where processing cost is noticeable is reanalysis. MacDonald, Just, and Carpenter (1992) reported that their high-span readers understood the English GP sentence in (6) more correctly than low-span readers.

(6) The experienced soldiers warned about the dangers conducted the midnight raid.

They claim that high-span readers with sufficient working memory capacity can retain two representations corresponding to two possible interpretations of ambiguous word *warned* simultaneously for a longer time than low-span readers. Therefore, when *warned* is disambiguated as a past participle at the end of the sentence, its representation is available for high-span readers. They claim this is the reason for the more correct interpretation of garden path sentence by high-span readers.

If our HSG have greater abilities than M/LSG for costly processing, error rates in comprehension questions for EB and LB will be lower for HSG than for M/LSG, and the RTs at P4 for these two types of sentences will be shorter for HSG than for M/LSG.

(7) Prediction 2: Effect of verbal working memory constraints
RT at P4 and error rate in comprehension question: HSG $<$ MSG $<$ LSG

Results

The mean error rates in comprehension questions for the three sentence types and WIS groups are given in Fig. 1. In 2-factor ANOVA for the error rates with sentence type and WIS group as independent variables, the main effect of sentence type was significant [$F_1(2,170) = 309.24, MSe = .012, p < .0001$; $F_2(2,81) = 85.44$, $MSe = .017, p < .0001$]. The main effect of WIS group was significant in the subject analysis and marginally significant in the item analysis [$F_1(2,85) = 7.15$, $MSe = .013$, $p = .001$; $F_2(2,81) = 2.51$, $p = .088$]. The interaction of sentence type $\times$ WIS group was significant in the subject analysis [$F_1(4,170) = 2.93, p = .022; F_2 < 1$]. The differences of mean error rates between Control and EB, between Control and LB and between EB and LB were significant according to the REGWQ test. The correlation between the participants' WISs and their error rates were negatively significant in LB [$r(88) = -.337, p = .0012$], and marginally significant in EB [$r(88) = -.182$, $p = .090$].

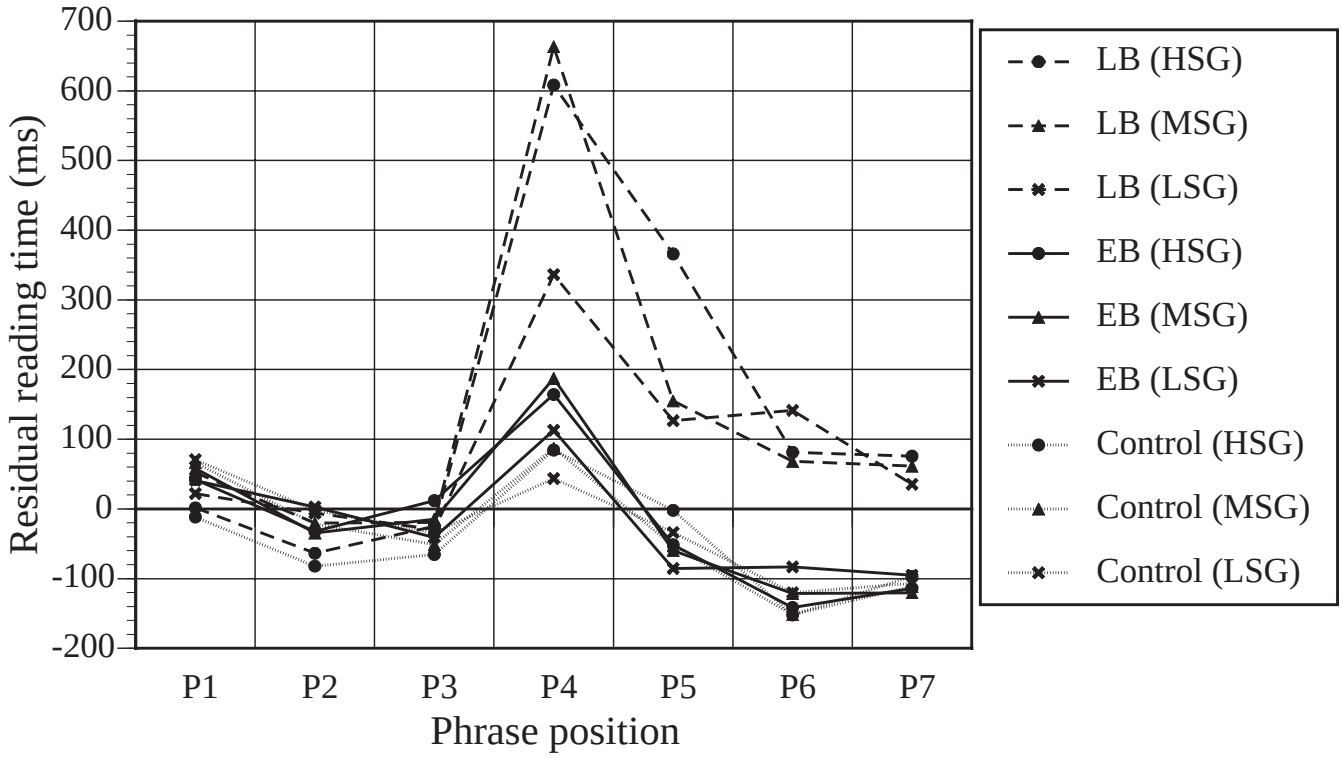


Fig. 2. Mean residual reading times for three sentence types and WIS groups at seven phrase positions (ms)

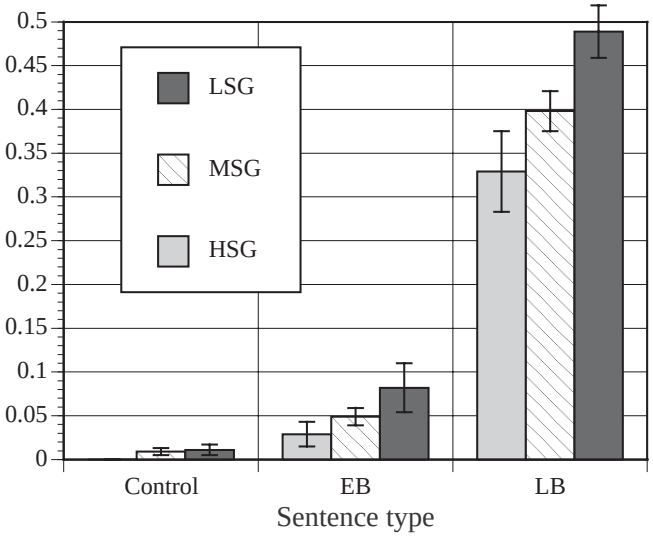


Fig. 1. Mean error rates in comprehension questions with standard errors for three sentence types and WIS groups

The mean residual RTs of the eighty-eight participants for the three sentence types and WIS groups at seven phrase positions are represented in Fig. 2. These residual RTs were calculated by subtracting the participants' predicted RTs for a phrase derived by their linear multiple regression equations with the number of characters and that of morae of the phrase as independent variables from the raw RTs (Mazuka, Itoh, & Kondo, 1997, 2002; Miyamoto, Gibson, Pearlmutter, Aikawa, & Miyagawa, 1999). An end point was counted as a phrase (P7) with one character and two morae. A 3-factor ANOVA for the residual RTs with sentence type, WIS group and phrase position as independent variables was carried out. The main effects of sentence type and of phrase position were significant [sentence type: $F_1(2,170) = 57.58, MSe = 72109, p < .0001; F_2(2,567) = 95.87, MSe = 17004, p < .0001$, and phrase position: $F_1(6,510) = 30.71$, $MSe = 88238$, $p < .0001$; $F_2(6,567) = 62.57$, $p < .0001$]. The interaction of sentence type $\times$ phrase position was significant [$F_1(12,1020) = 26.06$, $MSe = 27869$, $p < .0001$; $F_2(12,567) = 16.77$, $p < .0001$]. The interaction of phrase position $\times$ WIS group was marginally significant in the subject analysis and significant in the item analysis [$F_1(12,510) = 1.68, MSe = 88238, p = .068$, $F_2(12,567) = 3.27, p < .0001$]. The interaction of sentence type $\times$ phrase position $\times$ WIS group was significant in subject analysis [$F_1(24,1020) = 1.61, MSe = 27869, p = .032$; $F_2 < 1$]. In 2-factor ANOVAs for the residual RTs at seven phrase positions with sentence type and WIS group as independent variables, the main effect of sentence type was significant from P4 to P7 [P4: $F_1(2,170) = 51.22$, $MSe = 91383$, $p < .0001$, $F_2(2,81) = 55.95$, $MSe = 32847$, $p < .0001$, P5: $F_1(2,170) = 42.56$, $MSe = 42110$, $p < .0001$, $F_2(2,81) =$

19.34, $MSe = 36376$, $p < .0001$, P6: $F_1(2,170) = 24.99$, $MSe = 52206$, $p < .0001$, $F_2(2,81) = 25.60$, $MSe = 20009$, $p < .0001$, and P7: $F_1(2,170) = 30.02$, $MSe = 21609$, $p < .0001$, $F_2(2,81) = 32.93$, $MSe = 8251$, $p < .0001$]. At these four positions, the mean residual RTs in LB were significantly longer than those in Control and EB. Further, the REGWQ test for LB indicates that the mean residual RTs of HSG and MSG were significantly longer than that of LSG at P4, and that the mean residual RT of HSG was significantly longer than those of MSG and LSG at P5.

Discussion

The mean error rates in questions for EB and LB were significantly greater than that of Control, and the rate for LB was significantly greater than for EB. The residual RTs for LB were significantly longer than those for EB from P4 to P7. These indicate that a reanalysis in EB was associated with a psychologically measurable cost and that a reanalysis in LB was more costly than in EB, as predicted. [4]

The mean error rates of HSG and of MSG were significantly lower than that of LSG, and for LB the mean rates of HSG and of MSG were significantly lower than that of LSG as predicted. Especially for LSG, we recognize no significant difference between their mean error rate for LB and chance level. This means that LB was unprocessable for LSG. Contrary to our prediction, however, in LB the mean residual RTs of HSG and of MSG at P4 were significantly longer than that of LSG, and that of HSG at P5 was significantly longer than those of MSG and of LSG. This means that while HSG performed a more precise processing for a costly reanalysis in LB, they tended to spend longer time than (M/)LSG for its processing. In the Capacity Constrained Parsing Model advocated by MacDonald et al. (1992) (and the Capacity Constrained Concurrent Activation-based Production System by Just, Carpenter, and Keller (1996) and Just and Varma (2002)), working memory capacity is assumed to be shared by storage and processing. The assumption here is that much working memory capacity assures quick processing. Our HSG, however, spent a more time than LSG for the processing of P4 and P5 in LB. This suggests that the efficiency in language processing often emphasized for high-span readers does not necessarily mean rapidity in costly reanalyses.

Peculiarity of Japanese Local Ambiguity. We should note here that the property of local ambiguity in our experiment is different from that in MacDonald et al. (1992). That is, most of the local ambiguities in English associated with GP effect arise from lexical ambiguities, namely, the coincidence of a past tense and the corresponding past participle forms as in Bever's (1a) (*raced*) and (6) (*warned*), the ambiguity of *that* between complementizer and relative pronoun as in (8a), and the ambiguity of the subcategorization frame of a verb as in (8b) (*jog*) and (8c) (*warned*).

(8) a. The doctor told the patient that he was having trouble with to leave.

b. Since Jay always jog a mile seems like a short distance to him.

c. I warned John would come soon.

On the other hand, the local ambiguity at P3 in our experimental stimuli is purely structural. It is possible, therefore, that the response pattern concerning WIS difference found in our experiment is exclusively due to the head-final nature of Japanese. We thus examine reanalysis costs in Japanese sentences with local lexical ambiguity in the next section.

Experiment 2

This experiment is designed to examine whether the more precise comprehension and the longer (residual) RT at a costly reanalysis of HSG than (M/)LSG in experiment 1 is also observed for Japanese sentences with local lexical ambiguity.

Method

Participants. Sixty-six students of Mejiro University participated in the study for payment. They are Japanese native speakers. Their mean WIS by the Japanese Reading Span Test was 10.91 (SD=6.28). They were divided into three groups by the same way with Experiment 1, namely, nine as HSG, forty-four as MSG and thirteen as LSG.

Stimuli. Two types of Japanese sentences including a homonym in *hiragana* that is ambiguous between nominal and verbal interpretations were examined as experimental sentences. A sentence in which a homonym is interpreted as noun is an 'N-sentence', and a sentence with verbal interpretation is a 'V-sentence'. An example for each type is shown below.

[4] The subject of a relative clause in LB is primarily interpreted as the person in P1. However, since a Japanese subject referring to the speaker can be always phonetically null, the subject of a relative clause in LB can be the speaker secondarily. When the subject of P3 is required to be specified at P4, the person in P1 will be most easily accessed as the candidate for the subject since it was processed just now and is still activated (Most Recent Filler Strategy (Frazier, Clifton, & Randall, 1983) and Active Filler Strategy (Frazier & d'Arcais, 1989)). Pritchett (1992) points out that a local ambiguity can cause garden-path effect but a global ambiguity does not. Therefore, this global ambiguity in LB should not be the reason for the great processing cost in this sentence.

Hirose (2003) experimentally demonstrates that two successive accented phrases construct a prosodic major phrase in Japanese, and that the boundaries of this major phrase can ease or hinder reanalysis in Japanese relative clause structures. A reanalysis in which a syntactic clause boundary coincides with the prosodic major phrase boundary is preferred to one where it does not. In our control and experimental sentences, all P1s are accented. As for P2, five in Control, three in EB and eight in LB are accented. Control thus should be neutral for the effect of major prosodic boundaries. In the three sentences of EB where P1 and P2 are accented, the reanalysis at P4 should be hindered. In LB, on the other hand, the reanalyses should be facilitated in the eight sentences where major prosodic boundaries are placed between P2 and P3. Our results thus indicate that the reanalysis in LB is more costly than in EB even when prosodic major phrases are utilized in the reanalyses.

(9) a. N-sentence

R(egion)1			R2
Yamada-san-ga			jibun-no ie-ni
Mr. Yamada-NOM			self-GEN house-DAT
R3	R4	R5	R6
kaeru to	totemo	kireina	nettaigyo-o
frog and	very	beautiful	tropical fish-ACC
R7	R8		
motte kaetta	.		
carrying got back			

'Mr. Yamada got back home with a frog and a very beautiful tropical fish.'[5]

b. V-sentence

R1			R2
Yamada-san-ga			jibun-no ie-ni
Mr. Yamada-NOM			self-GEN house-DAT
R3	R4	R5	R6
kaeru to	totemo	kireina	okusan-ga
get back home and	very	beautiful	his wife-NOM
R7	R8		
rusudatta	.		
was away			

'When Mr. Yamada got back home, his very beautiful wife was away from home.'

Each experimental sentence was divided into seven regions and an end-point. The two types of sentences are identical from R1 to R5 to closely examine the processing of a homonym and its effect on the following interpretation possibly involving reanalysis. An R1 is a human NP nominatively marked by *ga*. An R2 is an NP marked accusatively by *o* or datively by *ni*. An R3 is a phrase in *hiragana* including a homonym that can be interpreted as a noun or a verb taking the R1 and R2 as its arguments. In Japanese orthography, the ambiguity of Region 3 can be avoided by Chinese characters. In (9), for example, the nominal interpretation of *kaeru* can be exclusively represented by Chinese character '蛙' (frog) and the verbal by '帰る' (get back home). An R4 and an R5 are adverbs or adjectives modifying R6 or/and R7. The R4 and R5 are intended to be a delay to establish the interpretation of R3. These two regions correspond to *about the dangers* in (6). An R7 includes the main verb and finally disambiguates the interpretation of R3.[6] The stimulus sentences were written in the standard Japanese orthography except for R3. One N- and one V-sentence were made from one homonymous phrase, and two experimental scripts were written so that five of each type of sentence were included in the main session. For the ten homonyms, their naturalness of writing in *hiragana*, familiarity (Amano & Kondo, 1999) and frequencies (*Asahi* Newspaper Digital Archives from 1984 to 2001) were controlled so that their lexical properties may not bias their interpretations. These statistics of the ten ambiguous words are shown in Table 1. Participants encountered ten homonyms only once each in the experiment. Thirty experimental sentences irrelevant to the purpose of this study were also included in the main session. Forty other sentences were included in the main session as fillers. Twenty of them were simple sentences, and the other twenty were complex sentences.

Procedure. The experiment was conducted on a Power Macintosh G4 running PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) with a Button Box. Sentences were presented on a computer screen by the region-by-region, self-paced, non-cumulative, moving-window reading paradigm. The characters initially appeared as dots, and participants pressed the rightmost button of the Button Box to reveal each subsequent region of the sentence and cause all the regions to revert to dots. In the same way with Experiment 1, a Yes/No question followed each sentence, and two kinds of audio response for correct or incorrect answers were given to the participants as feedback. The participants of three WIS groups were assigned randomly to the two experimental scripts, and the order of the presentation of stimulus sentences was randomized for each participant. The practice session included five trials. The experiment took the participants approximately twenty-five minutes.

Predictions

It is widely known that when a word is recognized, all the semantic contents of it are activated (Tanenhaus, Leiman, & Seidenberg, 1979; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). When R3 is encountered, therefore, two interpretations corresponding to its nominal and verbal meanings must be examined. If the syntactic dependency constraint discussed in Experiment 1 is imposed to the interpretation of R3, this region will be disambiguated as a verb to construct a clause structure with R1 and R2 as its arguments. This clause structure is maintained in V-sentence, but it must be revised at R7 in N-sentence. In this reanalysis, the nominal interpretation abandoned four regions before must be reactivated in addition to the structural recomputation canceling the dependency between R1, R2 and R3. The reanalysis cost in N-sentence is thus predicted to be quite noticeable. The error rates in questions will be higher for N-sentences than V-sentences. Further, if the response pattern in Experiment 1 is replicated in sentences with local lexical ambiguity, the mean error rate of HSG for N-sentences will be lower than those of M/LSG, and the mean residual RT of HSG at R7 will be longer than those of the other two groups.

[5] *San* is one of the honorific titles in Japanese, which can be used for males and females. Here we gloss it as "Mr." for simplicity.

[6] The argument structures of the two types of sentence are quite different from each other because this structure varies depending on the presence or the absence of a verb. The regions from R1 to R5 are required to be identical in order to examine the processing and the effect of homonyms. Because of these limitations, it was impossible to make semantically and pragmatically natural experimental sentences with the numbers of phrases in them being the same. The numbers of characters and morae are controlled for R6 and R7 between N- and V-sentences. For the details of experimental sentences, consult Appendix B.

Table 1
Experiment 2: Mean Statistics of Lexical Properties of Homonyms and t-values by Paired Means Comparison (SD)

	d f	Naturalness of writing in *hiragana* scaling from 1 (unnatural) to 5 (natural)	Familiarity scaling from 1 (very unfamiliar) to 7 (very familiar)	Frequency in *Asahi* Newspaper from 1984 to 2001
Noun interpretation		3.33 (.28)	6.12 (.46)	7247 (9280)
Verb interpretation		3.22 (.26)	6.15 (.24)	2896 (48062)
t-value	9	-.125	.815	-1.61

Results

Error Rate in Questions. The mean error rates for two sentence types and three WIS groups are given in Fig. 3.[7] A 2 × 3 ANOVA for arcsine-transformed values of error rates with sentence type and WIS group as independent variables was carried out. The main effect of sentence type was significant [$F_1(1,63) = 97.18, MSe = .046, p < .0001; F_2(1,54) = 43.91, MSe = .107, p < .0001$]. The main effect of WIS group was also significant [$F_1(2,63) = 6.03, p = .004; F_2(2,54) = 3.59, p = .035$]. The HSD test indicates that the values of HSG are significantly smaller than that of LSG, and the difference between HSG and MSG is marginally significant by LSD test. The interaction of sentence type × WIS group was not significant [Fs< 1].

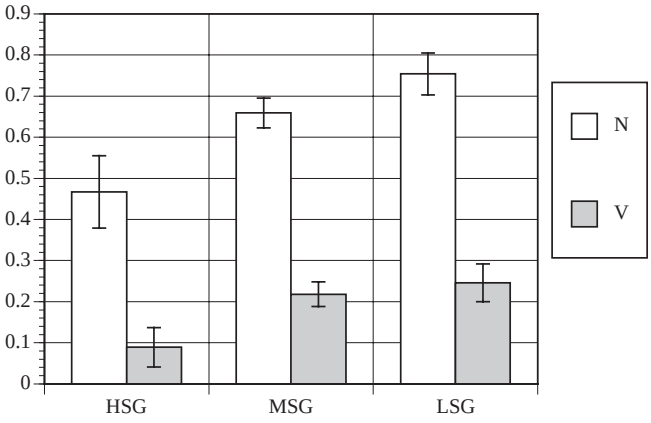


Fig. 3. Experiment 2: Mean Error Rates in Questions with Standard Errors for Two Sentence Types and Three WIS Groups

Residual Reading Time. The mean residual RTs for two sentence types and three WIS groups at eight regions are represented in Fig. 4. A 3-factor ANOVA for the residual RTs with sentence type, WIS group and region as independent variables was carried out. The main effect of sentence type was significant [$F_1(1,1008) = 29.62, MSe = 99109, p < .0001; F_2(1,432) = 30.93, MSe = 67253, p < .0001$]. The main effect of region was significant [$F_1(7,1008) = 10.66, p < .0001; F_2(7,432) = 11.15, p < .0001$]. The interaction of sentence type × region was also significant [$F_1(7,1008) = 8.93, p < .0001; F_2(12,432) = 9.24, p < .0001$]. The mean residual RTs of N-sentence are significantly longer than those of V-sentence from R6 to R8. The interaction of sentence type × WIS group was significant at R7.

Discussion

The mean residual RTs for N-sentence are significantly longer than those for V-sentence from R6 to R8. These strongly suggest that a reanalysis is performed for N-sentence at R7 and thus the verbal interpretation of R3 is established by the input of R6 at latest.[8] The significantly higher error rate for N-sentences than V-sentences is understood as the consequence of costly reanalysis in the former. This response pattern suggests that the syntactic dependency constraint for a predicate and its argument(s) is imposed to the interpretation of R3.

The mean error rate in questions of HSG is significantly lower than that of LSG as predicted, and the difference between HSG and MSG was marginally significant. This suggests the reliable ability of HSG for accurate comprehension. The mean residual RT of HSG for N-sentences at R7 is significantly longer than that of MSG and is marginally significantly longer than that of LSG. We can thus conclude that the response pattern of HSG in Experiment 1, namely, the higher accuracy and longer RT than M/LSG, is replicated in this experiment.

[7] Because of the difference of thematic structure between N- and V-sentences noted in footnote 6, the questions in experiment 2 are made to require true-false judgments on their propositional content. Therefore, chance level for the error rate is not exactly .5.

[8] The longer residual RT for N-sentence than V-sentence at R6 suggests that a reanalysis is beginning at this region. This would be because the nominal interpretation of R3 is semantically paired with the expression in R7 in some sentences. For example, *osu* (male/push) in R3 of Example 3 (Appendix B) can be paired with *mesu* (female) in R6. It is possible that when *mesu* is processed, the interpretation semantically related to *osu* as 'male' is reactivated to some extent. Also in other sentences, we can recognize semantic relevance between the nominal interpretation of R3 and the expression in R6, namely, *kiku* (chrysanthemum/hear) and *bara* (rose) in 2, *tsuru* (crane/angle) and *hakuchoo* (swan) in 3, *matsu* (pine tree/wait) and *sakura* (cherry) in 5, *huku* (clothes/breathe out) and *keshoohin* (cosmetics) in 7 and *mizu-ni* (water-DAT/seeing not) and *shizumete* (sinking) in 9. It is plausible that these semantic relevances reactivate the nominal interpretations of R3. We should note, however, that even though the semantic relevance primes the reanalysis, the ambiguity of R3 cannot be resolved before the end of the sentence.

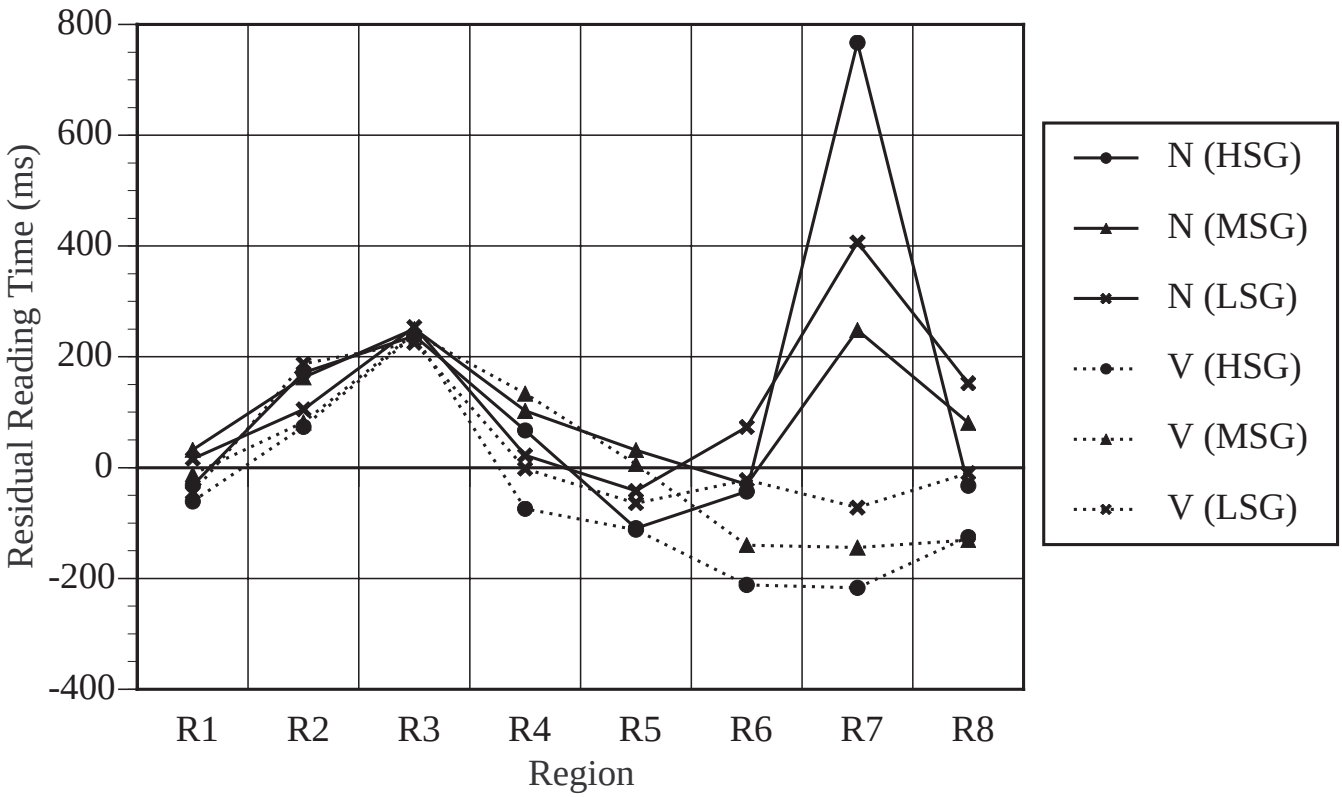


Fig. 4. Experiment 2: Mean Residual Reading Times for Two Sentence Types and Three WIS Groups at Eight Regions (ms)

We should also note that the main effect of WIS group was significant in item analysis at R4 and R5 and marginally significant in subject analysis at R5. The HSG spent relatively shorter time for these regions than M/LSG. This means that the post-processing of an ambiguous region is more costly for M/LSG than for HSG. A possible source of this shorter residual RT of HSG is the timing difference in operation of syntactic constraint. That is, HSG may be more quick in utilizing the syntactic dependency constraint than M/LSG in structure building. Then the unpreferred nominal interpretation is discarded rapidly in HSG, and thus this interpretation does not interfere with the preferred verbal interpretation. Hence the relatively lower error rate and the shorter residual RT at R7 of HSG for V-sentence are observed.

General Discussion

Implications to Parsing Model: Monotonicity in Structure Building and Syntactic Constraint

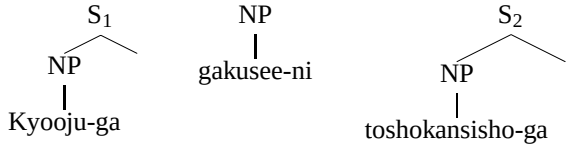
Our experimental results show that clausal interpretation is established immediately when it is possible. This suggests that syntactic dependency constraints is operating before the end of a sentence. Our results further show that cost of reanalysis differs among constructions, and that a reanalysis involving more elements is more costly. This means that the degree of a reanalysis cost can be explained in terms of monotonically incremental principle in structure building and syntactic dependency constraints. Our results thus should be empirical supports for principle-based parsing models in Japanese (e.g., Abney (1987, 1989); Gibson (1991); Crocker (1996); Pritchett (1988, 1992)). Kamide and Mitchell (1999) argue against principle-based parsing on the basis of their experimental results for the attachment preference of a globally ambiguous *ni*-marked NP. They reported that *gakusee-ni* (student-DAT) in (10) is preferred to be interpreted as the dative object of the main verb, *miseta* (showed).

(10) Kyooju-ga gakusee-ni toshokansisho-ga kasita
professor-NOM student-DAT librarian-NOM lent
muzurasii komonjo-o miseta.
unusual ancient manuscript-ACC showed
'The professor showed the student the unusual ancient manuscript which the librarian had lent.' (for main verb attachment)
'The professor showed the unusual ancient manuscript which the librarian had lent the student.' (for subordinate verb attachment)

If the syntactic dependency constraint is strictly applied at *kasita* (lent), *gakusee-ni* will be analyzed as the dative object of this verb. They claim that this attachment preference of *gakusee-ni* to the main verb is a counter-evidence against principle-based parsing. We should note here that the second

ga-marked NP *toshokansisho-ga* (librarian-NOM) indicates the presence of a subordinate clause since Japanese does not have a predicate taking the sentence initial three NPs in (10) as its arguments. Further, at the input of *toshokansisho-ga*, the main VP to which *gakusee-ni* is attached is not projected from the main verb, which is not processed yet. The phrase structure at this processing point is thus (11).

(11)



In (11), *gakusee-ni* is determined to precede S_2. To analyze *gakusee-ni* as an argument of *kasita*, this precedence relation must be cancelled. Since this should be a violation of monotonicity in structure building, *gakusee-ni* is left unattached. When the main verb *miseta* is processed, this unattached NP easily attaches to the main verb. The experimental result of Kamide and Mitchell (1999) should not be the counter evidence for incremental principle-based parsing.

Implications to Working Memory Model

Many of preceding psycholinguistic literature emphasize the efficiency of HSG in language comprehension. Our results revealed, however, that HSG spent longer time than LSG in costly reanalysis. We demonstrated that compositional symbolic representation was effective to explain the degree of processing cost. Let us thus assume a mental workspace for symbolic computation. Further, if HSG have a larger workspace than LSG, the different processing strategies of these groups directly follows. That is, in a costly reanalysis, many of the preceding dependencies are cancelled, and the input items must be retained independently for recomputation. The LSG do not have a workspace large enough to retain many unstructured items simultaneously, and thus when a costly reanalysis is required, the recomputation is abandoned. Hence the short RT and high error rate. The HSG, on the other hand, have a large workspace to retain many unstructured items simultaneously and thus can recompute the symbolic representations. This recomputation, however, requires much mental resources corresponding to the many processes for reanalysis. The HSG thus spend long time to attain accurate comprehension.

Just and Carpenter (1992) propose a capacity theory of language processing where language processing and storage share the same working memory resource pool (also, Just et al. (1996); Just and Varma (2002)). On the other hand, Caplan and Waters (1999) postulate two distinct verbal working memory processes, namely, *interpretive process* and *post-interpretive process*, where the former is assumed to be unconscious and obligatory and the latter is conscious and controlled (also, Waters and Caplan (1996); Caplan and Waters (2001, 2002)). Caplan and Waters (1999) claim that these two processes utilize distinct working memory resources, and that (Japanese) Reading Span Test reflects the function of post-interpretive process. LB in Experiment 1 and N-sentence in Experiment 2 are GP sentences associated with conscious processing difficulty. The effect of WIS group was significant only for these two types of sentence. For EB, Control and V-sentence, the effect of WIS did not reach significant level. Our experimental results thus suggest that (Japanese) Reading Span Test is more deeply related to costly conscious processes, which accords with Caplan and Waters (1999).

Some Speculations on Limitation of Working Memory

Miyake and Shah (1999) point out some unresolved theoretical issues on working memory, one of which is functional significance of limited working memory. Many studies on individual differences have demonstrated that individuals with larger working memory capacities are almost always better off than those with smaller capacities in performing various cognitive tasks. Then the question is why working memory capacity is strictly limited if a large capacity is preferable and adaptive. In our experiments, HSG interpreted GP sentences more accurately than LSG. It is quite unlikely, however, that we encounter GP sentences in the daily use of language. Our LSG did not get the correct interpretations of GP sentences most of the time, but they read these sentences more quickly than HSG. If our linguistic knowledge and language processing system are organized to be adaptive for daily language use, it may be more efficient to neglect extremely rare constructions in the face of infinite number of sentences in a language in principle. Our results thus may suggest the advantageous aspect of the limitation of working memory in sentence comprehension.

References

Abney, S. P. (1987). Licensing and parsing. In J. McDonough & B. Plunkett (Eds.), *Proceedings of North Easten Linguistic Society* (Vol. 17). Amherst, MA.

Abney, S. P. (1989). A computational model of human parsing. *Journal of Psycholinguistic Research*, *18*, 129–144.

Amano, N., & Kondo, T. (1999). *NTT database series: Nihongo–no goitokusei (Lexical properties of Japanese).* Tokyo: Sanseidoo.

Bever, T. G. (1970). The cognitive basis for linguistic structures. In J. R. Hayes (Ed.), *Cognition and the development of language* (pp. 279–362). New York: John Wiley.

Caplan, D., & Waters, G. (2002). Working memory and connectionist models of parsing: A reply to MacDonald and Christiansen (2002). *Psychological Review*, *109*(1), 66–74.

Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*, *22*, 77–126.

Caplan, D., & Waters, G. S. (2001). Working memory and syntactic processing in sentence comprehension. *Cognitive Studies*, *8*(1), 10–24.

Chiappe, P., Hasher, L., & Siegel, L. S. (2000). Working memory, inhibitory control, and reading disability. *Memory & Cognition*, *28*(1), 8–17.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Method, Research, Instruments, and Computers*, *25*, 257–271.

Crocker, M. W. (1996). *Computational psycholinguistics.* Dordrecht: Kluwer Academic Publishers.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.

Fodor, J. D., & Ferreira, F. (Eds.). (1998). *Reanalysis in sentence processing.* Dordrecht: Kluwer Academic Publishers.

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

Frazier, L., & d'Arcais, G. B. F. (1989). Filler driven parsing: A study of gap filling in Dutch. *Journal of Memory and Language*, *28*, 331–344.

Gibson, E. (1991). *A computational theory of human linguistic processing: Memory limitations and processing breakdown.* doctoral dissertation, Carnegie Mellon University.

Gunji, T. (1987). *Japanese phrase structure grammar.* Dordrecht: D. Reidel Publishing Company.

Hirose, Y. (2003). Recycling prosodic boundaries. *Journal of Psycholinguistic Research*, *32*(2), 167–195.

Hirose, Y., & Inoue, A. (1998). Ambiguity of reanalysis in parsing complex sentences in Japanese. In D. Hillert (Ed.), *Syntax and semantics 31: A cross–linguistic perspective* (pp. 71–93). San Diego: Academic Press.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*, 122–149.

Just, M. A., Carpenter, P. A., & Keller, T. A. (1996). The capacity theory of comprehension: New frontiers of evidence and arguments. *Psychological Review*, *103*(4), 773–780.

Just, M. A., & Varma, S. (2002). A hybrid architecture for working memory: Reply to MacDonald and Christiansen (2002). *Psychological Review*, *109*(1), 55–65.

Kamide, Y., & Mitchell, D. C. (1999). Incremental pre–head attachment in Japanese parsing. *Language and Cognitive Processes*, *14*(5/6), 631–662.

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

MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, *24*, 56–98.

Masson, M. E. J., & Miller, J. A. (1983). Working memory and individual differences in comprehension and memory of text. *Journal of Educational Psychology*, *75*, 314–318.

May, C. P., Hasher, L., & Kane, M. J. (1999). The role of interference in memory span. *Memory & Cognition*, *27*(5), 759–767.

Mazuka, R., & Itoh, K. (1995). Can Japanese speakers be led down the garden path? In R. Mazuka & N. Nagai (Eds.), *Japanese sentence processing* (pp. 295–329). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mazuka, R., Itoh, K., & Kondo, T. (1997). Processing down the garden path in Japanese: Processing of sentences with lexical homonyms. *Journal of Psycholinguistic Research*, *26*(2), 207–228.

Mazuka, R., Itoh, K., & Kondo, T. (2002). Costs of scrambling in Japanese sentence processing. In M. Nakayama (Ed.), *Sentence processing in East Asian languages* (pp. 131–166). Stanford: CSLI Publications.

Miyake, A., Just, M. A., & Carpenter, P. A. (1994). Working memory constraints on the resolution of lexical ambiguity: Maintaining multiple interpretations in neutral contexts. *Journal of Memory and Language*, *33*, 175–202.

Miyake, A., & Shah, P. (1999). Toward unified theories of working memory: Emerging general consensus, unresolved theoretical issues, and future research directions. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 442–481). Cambridge University Press.

Miyamoto, E. T., Gibson, E., Pearlmutter, N. J., Aikawa, T., & Miyagawa, S. (1999). A U–shaped relative clause attachment preference in Japanese. *Language and Cognitive Processes*, *14*(5/6), 663–686.

Osaka, M. (1998). Yomi-to working memory (Reading and working memory). In N. Osaka (Ed.), *Yomi: Noo-to kokoro-no zyoohoosyori (Reading: Information processing of brain and mind* (pp. 239–262). Tokyo: Asakura Syoten.

Osaka, M., & Osaka, N. (1994). *Yomi–to Working Memory Yooryoo: Nihongo Reading Span Test niyoru sokutei* (Reading and working memory: Measurement by Japanese reading span test). *Shinrigaku Kenkyuu*, *65*(5), 339–345.

Pritchett, B. L. (1988). Garden path phenomena and the grammatical basis of language processing. *Language*, *64*, 539–576.

Pritchett, B. L. (1992). *Grammatical competence and parsing performance.* Chicago: University of Chicago Press.

Rosen, V. M., & Engle, R. W. (1998). Working memory capacity and suppression. *Journal of Memory and Language*, *39*, 418–436.

Seidenberg, M., Tanenhaus, M., Leiman, J., & Bienkowski, M. (1982). Automatic access of the meaning of ambiguous words in context. *Cognitive Psychology*, *14*, 489–537.

Tanenhaus, M., Leiman, J., & Seidenberg, M. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behavior*, *18*, 427–440.

Waters, G. S., & Caplan, D. (1996). The capacity theory of sentence comprehension: Critique of Just and Carpenter (1992). *Psychological Review*, *103*, 761–772.

Appendix A
Experiment 1: Control and Experimental Sentences

The first rows represent the characters presented to participants, the second their pronunciations and the third their glosses. The corresponding English translations are given in quotations.

Control sentences

1. 太郎が 小学生を いじめた
   Taro-ga shoogakusei-o ijimeta
   name$_m$-NOM primary school child-ACC bullied

事実に 祖母が 立腹した.
jijitu-ni sobo-ga rippukusita
fact-DAT grandmother-NOM got angry

‘My grandmother got angry at the fact that Taro had bullied a primary school child.’

2. 次郎が 友人を だました うわさに
   Jiroo-ga Yuujin-o damashita uwasa-ni
   name$_m$-NOM friend-ACC deceived rumor-DAT

京子が 悲しんだ.
Kyoko-ga kanashinda
name$_f$-NOM felt sad

‘Kyoko felt sad at the rumor that Jiroo had deceived his friend.’

3. 花子が セーターを 編んだ 事に
   Hanako-ga seetaa-o anda koto-ni
   name$_f$-NOM sweater-ACC knitted fact-DAT

母親が 感謝した.
hahaoya-ga kanshashita
mother-NOM appreciated

‘Hanako’s mother appreciated the fact that Hanako had knitted a sweater.’

4. 陽子が 日記を 燃やした 事実に
   Yoko-ga nikki-o moyashita jijitu-ni
   name$_f$-NOM diary-ACC burned fact-DAT

姉が 絶句した.
ane-ga zekkushita
elder sister-NOM was at a loss for words

‘Yoko’s elder sister was at a loss for words at the fact that Yoko had burned her diary.’

5. 優子が 会社を やめた 事に
   Yuko-ga kaisha-o yameta koto-ni
   name$_f$-NOM company-ACC resigned fact-DAT

父親が 驚いた.
chichioya-ga odoroita
father-NOM got surprised

‘Yoko’s father got surprised at the fact that she had left the company.’

6. 太郎が 恋人を 裏切った うわさに
   Taro-ga koibito-o uragitta uwasa-ni
   name$_m$-NOM girlfriend-ACC cheated rumor-DAT

健二が 反論した.
Kenji-ga hanronshita
name$_m$-NOM refuted

‘Kenji refuted the rumor that Taro had cheated his girlfriend.’

7. 次郎が 子供を なぐった 事実に
   Jiroo-ga kodomo-o nagutta jijitu-ni
   name$_m$-NOM child-ACC beat fact-DAT

祖父が 激怒した.
sohu-ga gekidoshita
grandfather-NOM got furious

‘Jiroo’s grandfather got furious at the fact that Jiro had beaten a child.’

8. 花子が 初任給を もらった 事に
   Hanako-ga shoninkyuu-o moratta koto-ni
   name$_f$-NOM starting salary-ACC got fact-DAT

両親が 涙ぐんだ.
ryooshin-ga namidagunda
parents-NOM melted into tears

‘Hanako’s parents melted into tears at the fact that she had got a starting salary.’

9. 陽子が ウィスキーを 飲みほした 事実に
   Yoko-ga wisukii-o nomihoshita jijitu-ni
   name$_f$-NOM whiskey-ACC drank off fact-DAT

先生が あわてた.
sensei-ga awateta
teacher-NOM lost his cool

‘Yoko’s teacher lost his cool at the fact that she had drunk off a bottle of whiskey.’

10. 優子が パンを 焼いた 事に
    Yuko-ga pan-o yaita koto-ni
    name$_f$-NOM bread-ACC baked fact-DAT

恋人が 喜んだ.
koibito-ga yorokonda
boyfriend-NOM was pleased

‘Yoko’s boyfriend was pleased at the fact that she had baked bread.’

Early boundary sentences

1. 太郎が 雑誌を 出版した
   Taro-ga zasshi-o shuppanshita
   name$_m$-NOM magazine-ACC published

編集者に 手紙を 送った.
henshuusha-ni tegami-o okutta
editor-DAT letter-ACC sent

‘Taro sent a letter to the editor who published a magazine.’

2. 次郎が くだものを 栽培した 農夫に
   Jiroo-ga kudamono-o saibaishita noohu-ni
   name$_m$-NOM fruit-ACC grew farmer-DAT

代金を 払った.
daikin-o haratta
price-ACC paid

‘Jiro paid the price to the farmer who had grown the fruit.’

3. 花子が ペンキを 塗った 職人に
Hanako-ga penki-o nutta shokunin-ni
name$_{f}$-NOM paint-ACC painted craftsman-DAT
お礼を 言った.
orei-o itta
thanks-ACC said
‘Hanako gave thanks to the craftsman who had painted (something).’

4. 陽子が おもちゃを こわした 男の子に
Yoko-ga omocha-o kowashita otokonoko-ni
name$_{f}$-NOM toy-ACC broke boy-DAT
キャンディーを あげた.
kyandi-o ageta
candy-ACC gave
‘Yoko gave a candy to a boy who had broken a toy.’

5. 優子が 焼き肉を 食べた 親友に
Yuko yakiniku-o tabeta sin’yuu-ni
name$_{f}$-NOM roast meat-ACC ate close frined-DAT
ガムを あげた.
gamu-o ageta
gum-ACC gave
‘Yuko gave chewing gum to her close friend who had eaten roast meat.’

6. 太郎が まぐろを 釣った 漁師に お茶を
Taro-ga maguro-o tutta ryooshi-ni ocha-o
name$_{m}$-NOM tuna-ACC caught fisherman-DAT tea-ACC
出した.
dashita
served
‘Taro served tea to the fisherman who had caught a tuna.’

7. 次郎が 新車を 設計した 技師に
Jiroo sinsha-o sekkeishita gishi-ni
name$_{m}$-NOM new car-ACC designed engineer-DAT
お世辞を 言った.
oseji-o itta
compliment-ACC said
‘Jiroo paid a compliment to the engineer who had designed a new car.’

8. 花子が 財布を 落とした 後輩に
Hanako-ga saihu-o otoshita koohai-ni
name$_{f}$-NOM wallet-ACC lost juniro-DAT
お金を 貸した.
okane-o kashita
money-ACC lent
‘Hanako lent some money to her junior who had lost his/her wallet.’

9. 陽子が 母親を なくした 同僚に
Yoko-ga hahaoya-o nakushita dooryoo-ni
name$_{f}$-NOM mother-ACC lost colleague-DAT
お見舞いを 送った.
omimai-o okutta
condolence-ACC sent
‘Yoko sent a condolence card to a colleague who had lost his/her mother.’

10. 優子が 足を くじいた 選手に
Yuko-ga ashi-o kujiita senshu-ni
name$_{f}$-NOM foot-ACC wrenched athlete-DAT
包帯を あげた.
houtai-o ageta
bandage-ACC gave
‘Yoko gave a bandage to an athlete who had wrenched his/her foot.’

Late boundary sentences

1. 太郎が 電池を 売った ラジオに
Taro-ga denchi-o utta rajio-ni
name$_{m}$-NOM battery-ACC sold radio-DAT
おまけで つけた.
omake-de tsuketa
giveaway as attached
‘Taro attached a battery as a giveaway to the radio which he sold.’

2. 次郎が 大金を 盗んだ タンスに
Jiro-ga taikin-o nusunda tansu-ni
name$_{m}$-NOM much money-ACC stole chest-DAT
こっそり 隠した.
kossori kasushita
secretly hid
‘Jiro hid much money secretly in the chest of drawers he had stolen.’

3. 花子が コーヒーを あたためた カップに
Hanako-ga koohii-o atatameta kappu-ni
name$_{f}$-NOM coffee-ACC warmed cup-DAT
たっぷりと そそいだ.
tappurito sosoida
plentifully poured
‘Hanako poured coffee plentifully into the cup she had warmed up.’

4. 陽子が ソーセージを ゆでた スパゲティーに
Yoko-ga sooseiji-o yudeta supagetii-ni
name$_{f}$-NOM sausage-ACC boiled spaghetti-DAT
すばやく 加えた.
subayaku kuwaeta
quickly added
‘Yoko added sausage to the spaghetti she had boiled.’

5. 優子が 食器を 買った テーブルに
Yuko-ga shokki-o katta teeburu-ni
name$_{f}$-NOM tableware-ACC bought table-DAT
きれいに かざった.
kireini kazatta
nicely decorated
‘Yoko nicely decorated the table she had bought with tableware.’

6. 太郎が テレビを 修理した
Taro-ga terebi-o shuurishita
$name_m$-NOM television set-ACC repaired

自転車に 静かに のせた.
jitensha-ni shizukani noseta
bicycle-DAT softly put on

'Taro put the television softly on the bicycle he had repaired.'

7. 次郎が ロープを 切った 丸太に しっかり
Jiro-ga roopu-o kitta maruta-ni shikkari
$name_m$-NOM rope-ACC cut log-DAT tightly

巻きつけた.
makitsuketa
wound

'Jiro tightly wound a rope around a log he had cut.'

8. 花子が 切手を 集めた マッチ箱に
Hanako-ga kitte-o atsumeta macchibako-ni
$name_f$-NOM stamp-ACC collected matchbox-DAT

大切に しまった.
taisetsuni shimatta
with care stored

'Hanako carefully put away stamps in the matchboxes she had collected.'

9. 陽子が セロテープを 破った ポスターに
Yoko-ga seroteepu-o yabutta posutaa-ni
$name_f$-NOM cellophane tape-ACC tore poster-DAT

ぴったりと 貼った.
pittarito hatta
precisely stuck

'Yoko stuck cellophane tape precisely to the poster she had torn.'

10. 優子が 刺身を 冷やした お皿に
Yuko-ga sashimi-o hiyashita osara-ni
$name_f$-NOM sliced raw fish-ACC cooled dish-DAT

ていねいに 盛りつけた.
teineini moritsuketa
carefully arranged

'Yuko arranged sliced raw fish carefully on the dish she had cooled.'

Appendix B
Experiment 2: Experimental Sentences

1. 山田さんが 壁のむこう側を
Yamada-san-ga kabe-no mukoogawa-o
Mr. Yamada-NOM wall-GEN the other side-ACC

おすと かなり 大きな
osu-to kanari ookina
male/push and rather big

(N) めすの犬の 小屋にしています.
mesu-no inu-no koya-ni shiteimasu
female-GEN dog-GEN kennel-DAT use as

'Mr. Yamada is using the space over the wall as a kennel for a male and a rather big dogs.'

(V) 穴が 空いてしまった.
ana-ga aiteshimatta
hole-NOM holed

'When Mr. Yamada pushed the other side of the wall, a rather big hole appeared.'

2. 田中さんが 駅までの道を
Tanaka-san-ga eki-made-no michi-o
Mr. Tanaka-NOM station-to-GEN way-ACC

きくと 背の高い きれいな
kiku-to se-no takai kireina
chrysanthemum/hear to the back-GEN tall beautiful

(N) バラで かざった.
bara-de kazatta
rose with decorated

'Mr. Tanaka decorated the way to the station with chrysanthemums and tall beautiful roses.'

(V) お嬢さんが 案内してくれた.
ojoosan-ga an'naishite-kureta
lady-NOM lead gave (to me)

'When Mr. Tanaka asked the way to the station, a tall beautiful lady led him there.'

3. 山田さんが 小魚を つると
Yamada-san-ga kozakana-o tsuru-to
Mr. Yamada-NOM small fish-ACC crane/angle and

とても 大切な
totemo taisetsuna
very important

(N) 白鳥のために 買ってきた.
hakuchoo-no tame-ni katte-kita
swan-GEN sake-DAT buy came

'Mr. Yamada bought small fishes for his crane and very cherished swan.'

(V) ペルシャ猫が 喜ぶ.
pelushaneko-ga yorokobu
Persian cat-NOM get pleased

'When Mr. Yamada angles small fishes, his very cherished Persian cat gets pleased.'

4. 山田さんが 自分の家に
Yamada-san-ga jibun-no ie-ni
Mr. Yamada-NOM self-GEN house-DAT

かえると とても きれいな
kaeru to totemo kireina
frog/get back home and very beautiful

(N) 熱帯魚を 持って帰った.
nettaigyo-o motte kaetta
tropical fish-ACC carrying went back

'Mr. Yamada got back home with a frog and a very beautiful tropical fish.'

(V) 奥さんが 留守だった.
okusan-ga rusudatta
his wife-NOM was away

'When Mr. Yamada got back home, his very beautiful wife was away from home.'

5. うちの社長が タクシーを まつと
uchi-no shachoo-ga takushii-o matsu-to
we-GEN president-NOM taxi-ACC pine tree/wait and

大きい 立派な
ookii rippana
big fine

(N) 桜の木のそばに とめてもらった.
sakura-no ki-no soba-ni tomete-moratta
cherry-GEN tree-GEN the side-DAT asked to stop

'Our president asked the taxi to park near a pine and a big fine cherry trees.'

(V) リムジンが やってくる.
limujin-ga yattekuru
limousine-NOM come

'When our president waits for a taxi, a big fine limousine comes.'

6. 外国の観光客が 日本に
gaikoku-no kankookyaku-ga nihon-ni
foreign country-GEN tourists-NOM Japan-DAT

きたから はるばる 遠い
kita-kara harubaru tooi
north from/came because all the way far

(N) 沖縄まで いっぱいだ.
okinawa-made ippaida
Okinawa as far as be full

'Foreign tourists can be seen in Japan everywhere from north to far Okinawa.'

(V) 観光地が にぎわった.
kankoochi-ga nigiwatta
tourist spot-NOM crowded with

'Since foreign tourists came to Japan, very far tourist spots are abounding in tourists.'

7. 田中さんが 新しいフルートを
Tanaka-san-ga atarashii huruuto-o
Mr. Tanaka-NOM new flute-ACC

ふくと 新発売の 高価な
huku-to shinhatsubai-no kookana
clothes/breathe out and brand new-GEN expensive

(N) 化粧品の代わりに 買った.
keshoohin-no kawari-ni katta
cosmetics-GEN alternative-DAT bought

'Mr. Tanaka bought a new flute in stead of clothes and brand new cosmetics.'

(V) ステレオより 良い音がする.
sutereo-yori yoi oto-ga suru
stereo more sound good

'When Mr. Tanaka plays the new flute, it sounds better than a brand new expensive stereo.'

8. お父さんが 小包の中身を
otoosan-ga kozutsumi-no nakami-o
father-NOM parcel-GEN content-ACC

みずに しばらくの あいだ
mizu-ni shibaraku-no aida
water-DAT/seeing not bit-GEN while

(N) 沈めて 濡らしてしまった.
shizumete nurashe-shimatta
sinking get wet

'My father sank the content of a parcel in the water for a while to get it wet (by mistake).'

(V) 押し入れに しまった.
oshiire-ni shimatta
closet-DAT put away

'My father put away a parcel into the closet for a while without seeing the content of it.'

9. 木村君が 新しいTシャツを
kimura-kun-ga atarashii tiishatsu-o
Kimura-NOM T-shirt-ACC

きずに しばらくの あいだ
kizuni shibaraku-no aida
wound-DAT/wearing not bit-GEN while

(N) 巻きつけて 止血した.
makitsukete shiketsusita
binding stanched

'Kimura staunched blood by binding a new T-shirt around a wound.'

(V) タンスに しまった.
tansu-ni shimatta
wardrobe-DAT put away

'Kimura put away a new T-shirt into the wardrobe for a while without wearing it.'

10. 鈴木さんが 近所の幼稚園に
Suzuki-san-ga kinjo-no yoochien-ni
Mr. Suzuki-NOM neighborhood-GEN kindergarten-DAT

よるまで かわいい 5 才の
yoru-made kawaii go-sai-no
night/drop in until pretty five age-GEN

(N) 長男を あずけている.
choonan-o azuketeiru
eldest son-ACC leaving in care

'Mr. Suzuki are leaving his pretty five-year eldest son in the care of the kindergarten in the neighborhood until night.'

(V) 長男は 勉強していた.
choonan-wa benkyoo-site-ita
eldest son-TOP was studying

'Until Mr. Suzuki dropped in the kindergarten in the neighborhood, his pretty five-year eldest son was studying.'