

PROCESSING OF JAPANESE GARDEN PATH, CENTER-EMBEDDED, AND MULTIPLY-  
LEFT-EMBEDDED SENTENCES:

READING TIME DATA FROM AN EYE MOVEMENT STUDY

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Introduction

Any model for human natural language processing should capture the basic properties of human natural language processing. We can identify three such properties. One such property is the apparent speed and efficiency of our processing. When we hear a sentence, we understand it almost instantaneously without any conscious effort. Marslen-Wilson (1973, 1974) reported that subjects can restore the semantic anomalies of input sentences when they are shadowing stimuli sentences very closely (300-800 msec).

A second property is that, although we are very efficient in processing natural language most of the time, we do seem to have difficulty in processing certain types of sentences. If we wish our model for natural language processing to be psychologically plausible, the model should be able to predict those processing difficulties.

A third property of natural language processing is the universality of such mechanisms. It is an empirical issue whether speakers of different languages use the same procedures in processing their native languages as adults (see Mazuka & Lust, to appear, for discussion on this issue). Apparently, however, we are born with the potential to process any natural language in the world. Thus, a model for natural language processing should be able to accommodate a whole range of languages in such a way as to capture this universality.

In this paper, we will report results from an exploratory study of Japanese sentence processing that tested sentences which, from previous psycholinguistic research in English processing, were predicted to cause processing difficulties; namely, (possible) garden path sentences, center-embedded sentences, and multiply-left-embedded sentences. First, we will discuss the linguistic characteristics of Japanese that are relevant to the current study. Then we will discuss our results for each type of sentence in relation to previous studies on English.

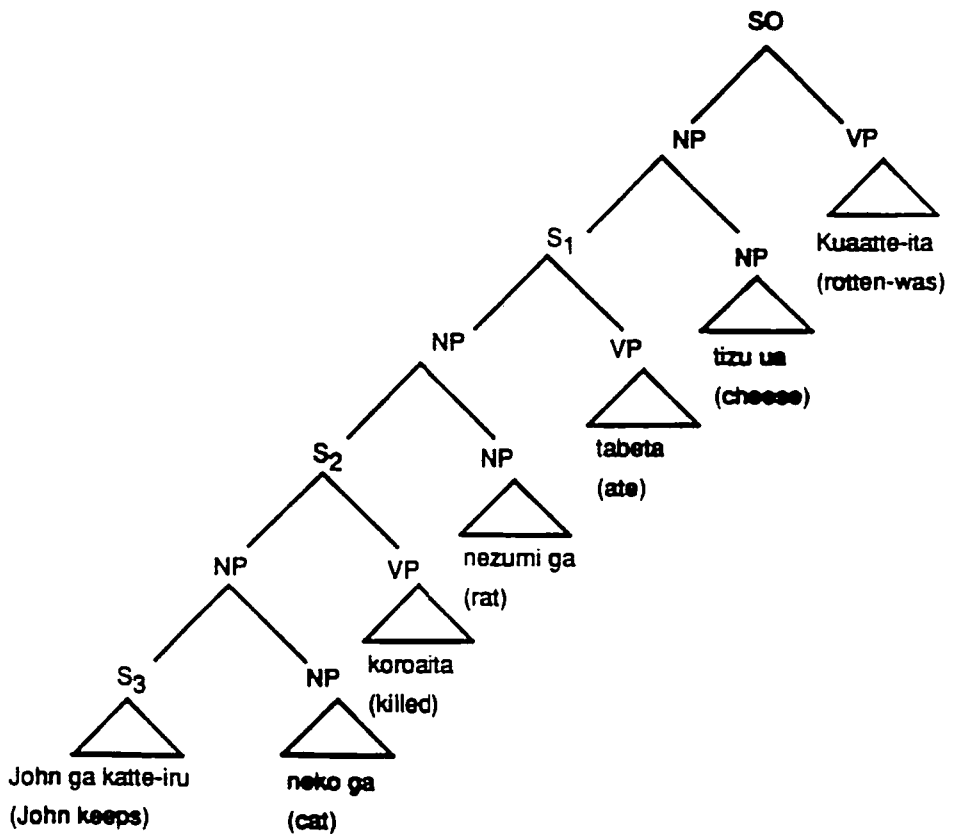
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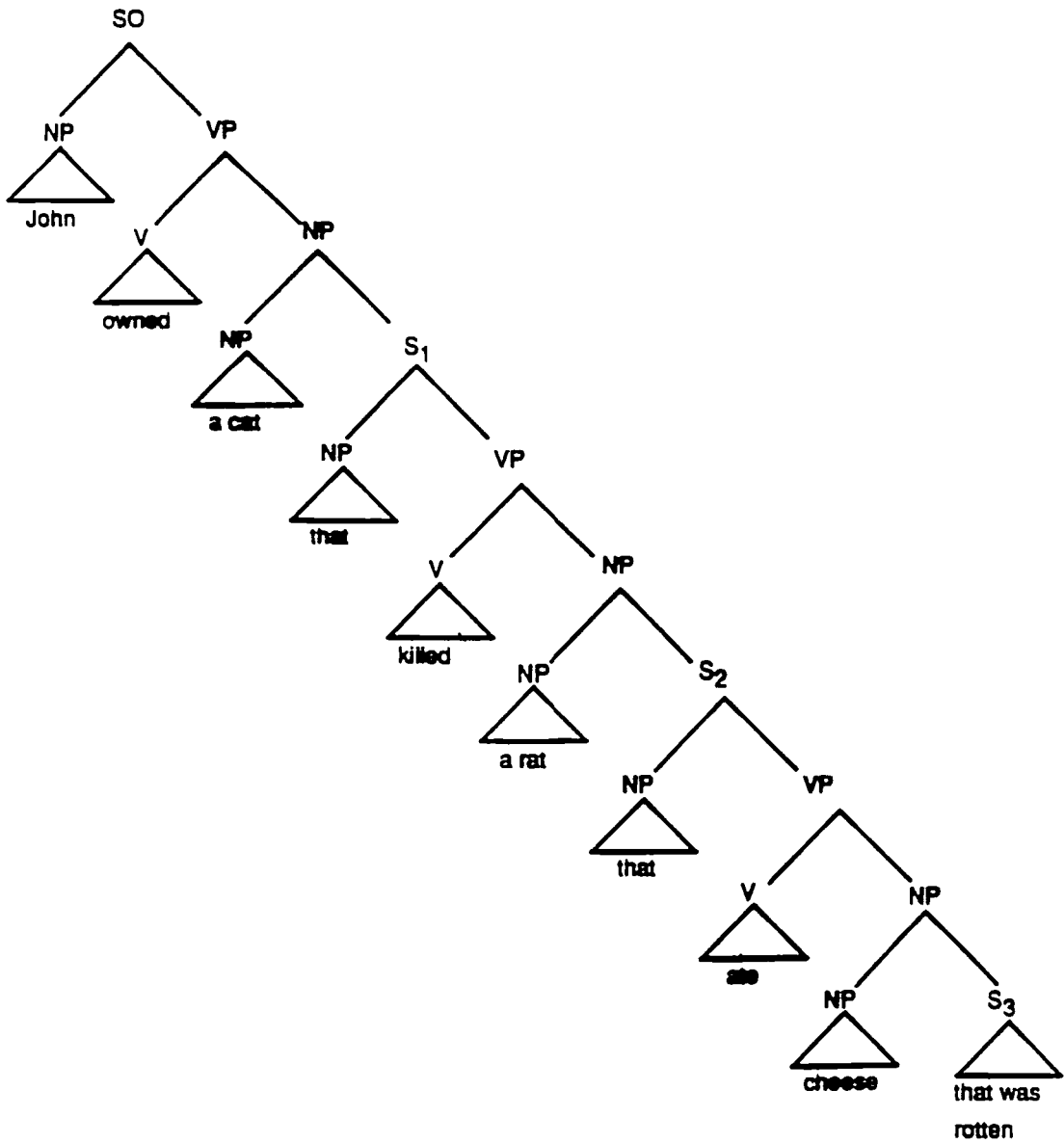
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**The cheese that the rat that the cat that John keeps killed ate was rotten.**  
**(Kuno, 1973,8)**

Fig. 1 An Example of Left-Branching Structure



John owned a cat that killed a rat that ate the cheese that was rotten.

(Kuno, 1973,9)

Fig. 2 An Example of Right-Branching Structure

Japanese

The basic word order of Japanese is SOV. Thus, a simple sentence in Japanese looks like (1).

- (1) **John ga Mary o mita.**  
 name N name A saw  
 "John saw Mary."

Furthermore, the order of lexical items are often the reverse of English, as in (2).

- (2) **Tokyo eki kara densha de ichijikan kurai nishi**  
 Tokyo station from tram by one hour about west  
 14 13 12 11 10 9 8  
**e itta tokoro ni Kamakura to iu machi ga arimasu.**  
 toward go place at Kamakura quote called town exists  
 7 6 5 4 3 2 1

"There is a town called Kamakura at a place (you can reach) going west  
 about one hour by tram from Tokyo Station."  
 9 10 11 12 13 14

Japanese is a head-final language, as opposed to English which is a head-initial language as in (3).

- |     |                                   |                               |
|-----|-----------------------------------|-------------------------------|
| (3) | Head-Final Language               | Head-Initial Language         |
|     | <u>Japanese</u>                   | <u>English</u>                |
|     | Complex Noun                      | Complex Noun                  |
|     | [[ Mary o mita] <u>John</u> ]     | [ <u>John</u> [who saw Mary]] |
|     | Adverbial Subordinate Clause      |                               |
|     | [John ga Mary o mita] <u>toki</u> | <u>when</u> [John saw Mary]   |

When a sentence in Japanese has an embedded clause, it branches out leftward as in Figure 1. Such languages are called "left branching." English is a right branching language as in Figure 2.

Japanese allows not only its subjects, but also other arguments to be dropped. Thus, the sentences in (4) are also grammatical.

- (4) a. e Mary o mita.  
 b. John ga e mita.  
 c. e e mita.

The order of arguments in Japanese sentences is not strictly fixed. Thus, while SOV is clearly the unmarked order, various permutations of arguments are also grammatical as in (5).

- (5) a. Mary ga Bill ni John o syookai-sita.  
           N          D          A          introduced  
 b. Bill ni Mary ga John o syookai-sita.  
 c. John o Bill ni Mary ga syookai-sita.

The location of a verb in a clause is strictly final.

Japanese noun phrases take particles (or post positions) that (roughly) indicate case. For example, Mary-ga indicates nominative case, John-o accusative case and Bill-ni dative.

Japanese orthography uses three types of characters. The first is Chinese characters called Kanji. Each Kanji signifies roughly one meaning, but can be read in many different ways depending on the compound it appears in. For example, the character signifying "head" (in 6) can be read "atama", "kasira", "too" or "zu" depending on context.

- (6) Kanji Character 頭 atama  
                           too  
                           kasira  
                           zu

Thus one Kanji may correspond to many moras. In addition to Kanji, Japanese uses two types of syllabic alphabets called Hiragana and Katakana. Each kana character in these syllabaries represents one mora. Ordinarily, Japanese sentences employ a mix of these three types of characters. Kanji is used for content words most often and Hiragana is used for particles and inflections. In print, each character takes up the same amount of space, and each mora takes approximately the same length of time when it is uttered. Thus, the written length of a sentence does not exactly correspond to its length when read aloud, depending on how many Kanjis are used and how many moras each Kanji represents.

## Method

### 1. Apparatus

Stimulus sentences were presented on a graphic display monitor (348mm x 278mm). The eye camera (Nack Eye Mark Recorder, Type V; using infra-red light reflection on the retina) was located 57cm away from the display screen. It monitored eye movement, recording eye location at 33.3 msec intervals. Eye movement was monitored for the right eye and the viewing was binocular. The subjects were provided with a chin rest, and their head location was fixed with a head band.

### 2. Material

7 types of sentences were tested: 3 types of garden path sentences, degree 1 and 2 center-embedded sentences, and multiple-left-embedded sentences with and without long-distance backward

left-embedded sentences with and without long-distance backward anaphora. (The structures of the test sentences are discussed later.) 5 sentences were constructed for each type, totalling 35 sentences. 5 sets of stimuli sentences were made such that each set contained two sentences of each type, and each sentence appeared in two of the stimuli sets. Thus, each stimuli set contained 14 test sentences (2 sentences x 7 types). Each stimuli set contained 45 other sentences as well. These included simple sentences and sentences with adverbial subordinate clauses, sentential subjects and relativised subjects. Simple sentences and sentences with adverbial subordinate clauses were used as control sentences. Thus, each stimulus set had 59 sentences. In addition, 22 of these sentences (approximately one in three sentences) were followed by a short sentence that started with two question marks. These were simple declarative sentences that described the content of the immediately preceding test sentences: about half of them were correct descriptions of the test sentences, while the other half were incorrect. Three sentences were presented at the beginning of the first session but were eliminated from the analysis. Thus, a stimulus set consisted of a total of 84 sentences, which was divided into 7 sessions, 12 sentences each.

### 3. Subjects

45 native speakers of Japanese participated in the study. The subjects were undergraduate students, graduate students or university faculty members in the Tokyo area. They were not paid. 9 subjects were assigned to each of the 5 stimuli sets. Since each test sentence appeared in two of the stimulus sets, 18 responses were recorded for each sentence.

### 4. Procedure

The initial calibration usually took 5 to 10 minutes. At the beginning of each session, a circular pattern appeared at the 4 corners of the screen, in the middle of each side, and at the center of the screen at 1.5 second intervals, in random order. Subjects were asked to follow the movement of the circle. Before each sentence, a cross appeared on the screen and subjects were told to focus on it. The cross corresponded to the beginning of a stimulus sentence. Subjects were asked to read the sentence normally, as if they were reading a book. They were asked to read as quickly as they normally do without sacrificing comprehension. The subjects would press a key on the keyboard when they finished reading each sentence, and the sentence would disappear from the screen. The total reading time was recorded. When a sentence beginning with two question marks appeared, subjects were asked to judge whether what it said was true based on the immediately preceding sentence. If true, they were asked to press 1 on the keyboard, and 2 if false.

## Center-Embedded Sentences

### 1. Background

It is widely assumed in linguistic and psycholinguistic literature that center-embedded sentences are difficult to process. An apparent difficulty in processing sentences such as (7) supports this assumption.

- (7) a. The man the teacher the girl loved taught died.  
b. The planet the aliens the astronomer saw landed on, exploded.

Some have argued that the difficulty of center-embedded sentences is caused by other factors, such as the location of gaps (Hakes, Evans & Brannon, 1976), and that when the degree of embedding is 1, the sentences do not have the strong effect of center-embedded sentences such as (7). However, at least in English, when there are 2 degrees of center-embedding, the difficulty of such sentences seems to be quite robust.

De Roeck, Johnson, King, Rosner, Sampson, and Varile (1982) reported that in German, degree 2 center-embedded sentences appear to be produced more frequently than in English. Thus, it is possible that the difficulty of center-embedded sentences is specific to English, and is not found in other languages such as Japanese.

Eady and Fodor (1981) experimentally tested the processing of center-embedded sentences and found that degree 2 center-embedded sentences did cause significant processing difficulties whether they appeared in the subject position of the main clause or in the object position, when such embedding caused three NPs to be stacked consecutively, as shown in (8)a and b.

- (8) a. [Jack met the patient [the nurse [the clinic had hired] sent to the doctor]]  
b. [The patient [the nurse [the clinic had hired] sent] to the doctor] [met Jack]

They suggested that there are two possible explanations for these difficulties, i.e., the presence of overlapping (or nested) filler-gap relations, or a difficulty caused by three consecutive NPs. Japanese is an ideal language to test these two possibilities, as center-embedded sentences can be created without nesting filler-gap relations.

### 2. Material

As shown in (9) and (10), 5 examples of degree 1 center-embedded sentences and 5 examples of degree 2 center-embedded sentences were constructed.

#### (9) Degree 1 Center-Embedded Sentences

- a. [Hiroshi ga [Masao ga e katta] pan o tabeta]  
name N name N bought bread A ate  
"Hiroshi ate the bread Masao bought"

- b. [Yuuiti ga [hahaoya ga e kaita ] memo o mituketa]  
 name N mother N wrote memo A found  
 "Yuuji found a memo his mother wrote"
- c. [Hiromi ga [Yuuko ga kazeo hiita] node mimai  
 name N name N cold caught because went  
 ni itta]  
 to visit  
 "Hiromi went to visit Yooko because she caught a cold"
- d. [e Titioya o [e hahaoya o keno siteiru] musuko ga  
 father A mother A hates son N  
 tayotte kita]  
 came for help  
 "The son who hated his mother came to his father for help"
- e. [e Tanaka ni [e Suzuki ni e kiita] nyusu o tsutaeta]  
 name D name D heard news A communicated  
 "(I) told Thanaka the news I heard from Suzuki"

(10) Degree 2 Center-Embedded Sentences

- a. [Yoko ga [Hiromi ga [Asako ga e kaita] genkoo  
 name N name N name N wrote draft  
 o kakinaosita] syorui o yonda]  
 A re-wrote papers A read  
 "Yoko read the papers that Hiromi re-wrote based on the draft Asako wrote"
- b. [Yuuko ga [Akio ga [Satoru ga e katte kita] mame  
 name N name N name N bought beans  
 o hiite e ireta] kochii o nonda]  
 A ground made coffee A drank  
 "Yuuko drank the coffee Asako made with the beans Satoru bought"
- c. [Yamaguti ga [tuma ga [titioya ga e nokosita] kabu  
 name N wife N father N left stocks  
 o utte e tukutta] kane de ie o tateta]  
 A sold made money I house A built  
 "Yamaguchi build a house with the money his wife made by selling the stock"
- d. [Akira ga [Tosiko ga [Hazime ga nakidasita] toki  
 name N name N name N start crying when  
 okidasita] no ni kizuita]  
 got-up that D noticed  
 "Akira noticed that Toshiko got up when Hajime start crying"
- e. [Mayumi ga [kodomo ga [syuuto ga e tukatte ita]  
 name N child N mother-in-law N was using  
 yunomi o kowasite simatta] node e atarasiku katte kita]  
 tea cup A broke because newly bought  
 "Mayumi bought a new teacup since the child broke the one her mother-in-law was using."



(9)a and b involve relative clauses modifying the main clause object noun. The first two NPs in these sentences both have the nominative particle -ga. The filler-gap relation is between the head noun and the object gap in the relative clause. (9)c involves adverbial subordinate clause embedding. It also involves two consecutive NPs marked by the nominative marker -ga, but this sentence does not have a gap. (9) d involves two consecutive NPs both marked with the accusative marker -o. If we consider the preposing of the object as a result of movement, then it involves two gaps. One is the subject position of the main clause, and the other the subject of the subordinate clause. Here, the filler-gap relation is nested. (9)e involves the two consecutive NPs marked with the dative marker -ni. As the embedded clause is a relative clause, it involves one filler-gap relation between the head noun and the object gap of the relative clause. But neither the subject of the main nor the subordinate clause is overtly present in the sentence, thus they do not involve filler-gap relations.

(10)a and b have two object relative clauses, one embedded within the other. In (10)a, the relative clause modifying the main clause object "syorui" (official papers) is a gapless relative construction. Thus the sentence has only one gap-filler relation. Both of the relative clauses in (10)b contain gap, but they do not involve nested gap-filler relations. (10) c has two relative clauses embedded, but the middle level relative clause modifies an instrumental NP. (10)d involves an adverbial subordinate clause and a sentential complement, and thus has no gap. (10)e has an adverbial clause at the middle level. Thus, none of the degree 2 center-embedded sentences has nested filler-gap relations.

Intuitively, degree 1 embedding does not seem to cause too much trouble, but degree 2 center-embedded sentences give the impression of incomprehensibility.

### 3. Results and discussion

The total reading time for each sentence was divided 1) by the number of characters in the sentence to calculate the reading time per character, and 2) by the number of moras to calculate the reading time per mora. As a control, reading times for simple sentences such as (11) and sentences with adverbial subordinate clauses such as (12) were also calculated.

(11)	Akanboo	ga	honyuubin	de	miruku	o	noda
	baby	N	bottle	I	milk	A	drank
	"The baby drank milk from the bottle"						

(12) [Hiroko ga asahayaku okita] toki e koohii  
 name N early in the morning got up when coffee  
 o ireta]  
 A made  
 "When Hioko got up early in the morning, she made some coffee"

It should be noted however, that control sentences had only one animate argument per clause in the subject position, whereas most of the test sentences involved two or more animate arguments. The same control sentences were used for other structures we discuss below.

Figures 3 and 4 show that both degree 1 and 2 center-embedded sentences took longer to read than the control sentences, and that the degree 2 sentences took nearly twice as long as the control sentences. The results show that the difficulty of center-embedded sentences is not restricted to English, and that it is also not because of nested filler-gap relations. It was also found that degree 2 center-embedded sentences were significantly more difficult than degree 1 center-embedded sentences.

The results seem to suggest that the difficulties of center-embedded sentences are due to consecutive NPs. However, the results of Japanese can further differentiate the proposed explanation. Eady and Fodor suggested three possibilities for the three consecutive NPs; 1) that they are misparsed as conjoined, 2) a six-word package is not a phrase (based on the Sausage Machine), 3) the first NP is not integrated into the semantic structure.

The Japanese conjunction marker for NPs, -to, cannot be used with NPs which are already marked by a case assigning particle such as -ga or -o. Thus, stacked NPs in the present experiment cannot be misanalyzed as being conjoined. For the second possibility, we cannot test the hypothesis in Japanese since it is not clear what constitutes a word in Japanese, and how the Sausage Machine should be applied to Japanese. However, the difficulty of degree 2 center-embedded sentences in English still exists even when the whole sentence consists of 6 words as in (13).

(13) a. Planets aliens astronomers saw liked exploded.

Thus, it seems unlikely that the difficulty is due to the six-cell package.

It appears, then, that the only possibility is the third, namely that the first NP cannot be integrated into the semantic structure readily. This hypothesis is based on the theory put forward by Marslen-Wilson, who proposed that humans try to establish the semantic representation of a sentence as rapidly as possible. When there are three consecutive NPs, the first NP cannot be incorporated into the semantic representation of the clause until much later in the sentence.

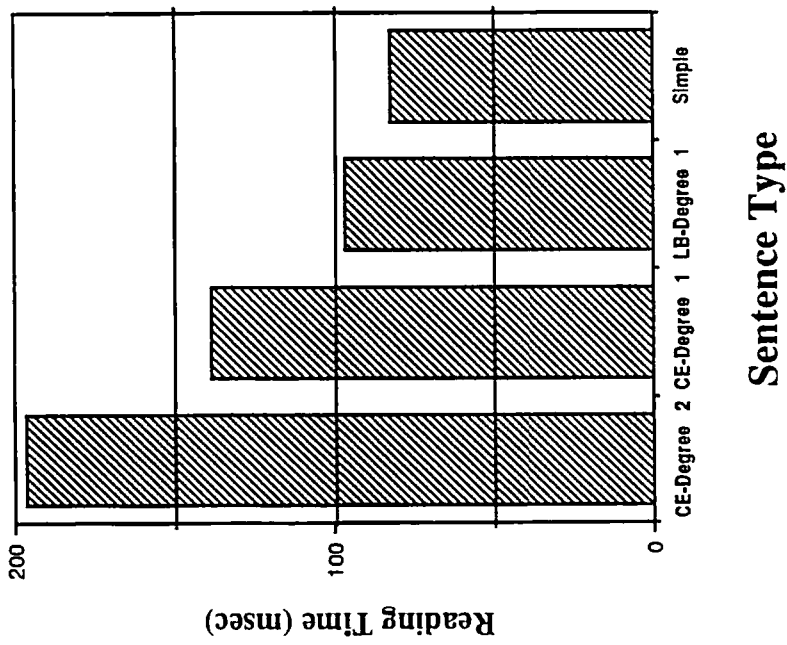


Fig. 3 Reading Time per Character for Left-Branching Sentences

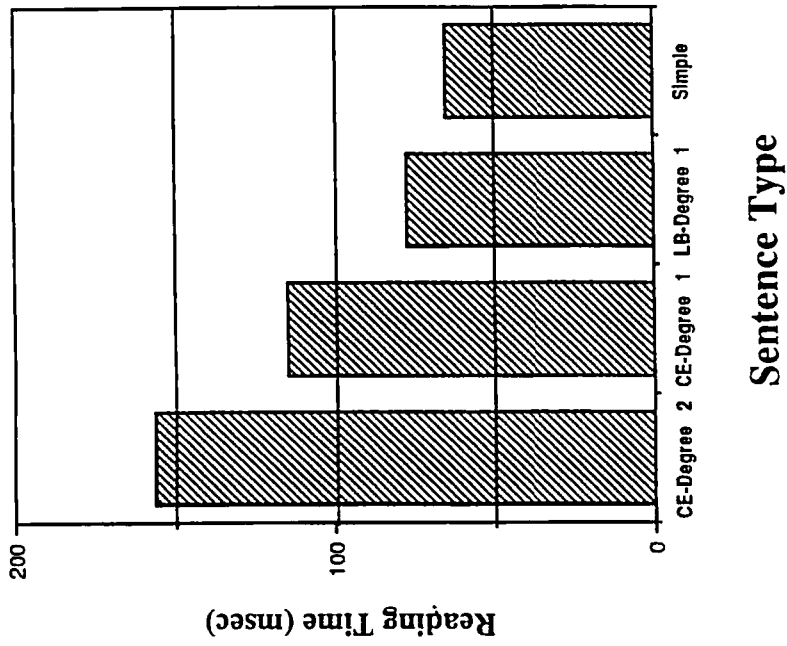


Fig. 4 Reading Time per Mora for Center-Embedded Sentences

However, an interesting aspect of Japanese center-embedded sentences is that if we drop the overt NPs, they become easily processible, at least intuitively. For example, if we drop the first two NPs from all of the sentences in (10) above, they do not give any impression of difficulty in comprehension. Dropping one NP also seems to help, but not as much as dropping two. (Without context, dropping all of the NPs make the sentence awkward.) Obviously, dropping NPs make the sentence more ambiguous as to where the gap should be located, but it does not seem to cause difficulty, at least at the conscious level. If delaying to build semantic representation caused the difficulty for the center embedded sentences, dropping overt NPs should not reduce the difficulty. Thus, the difficulty associated with center embedded sentences is probably caused by the surface string of stacked NPs, rather than by the assignment of argument structure at a deeper level.

## Garden Path Sentences

### 1. Background

Certain types of sentences in English, often called garden path sentences, are also known to cause processing difficulty. (14) a and b are well known examples of such sentences.

- (14) a. The horse raced past the barn fell.  
b. While Mary was mending the sock fell off her lap.

Although this phenomenon has been widely recognized, what is considered to be a garden path sentence varies from researcher to researcher. In the strictest sense, Pritchett (1987) defines it as "...local ambiguity in the input string [that] results in grammatical but unprocessable sentences." (p.1). According to this interpretation, only those sentences that require conscious processing difficulty are considered garden path sentences. For others such as Frazier (1983), any sentence can be considered a garden-path if "the processor (frequently) constructs an incorrect analysis of some portion of the sentence on the way to arriving at a correct analysis that is tenable for the entire sentence" (p.225). According to this definition, we may not always consciously experience processing difficulties for some garden path sentences.

Underlying both interpretations above is the idea that parsing mechanisms make misanalyses when local ambiguity is encountered, and reanalyze the ambiguity such that it is compatible with the whole sentence. Some of the reanalyses cause processing difficulties severe enough for English speakers to be aware of them. Others do not seem to cause the same kind of difficulties, although some problems may be experienced at an unconscious level.

Numerous proposals have been put forward to explain garden path phenomena, since the conditions under which a parsing model fails to make correct analyses offer a reflection of the model's structure. Pritchett (1987) has classified the various proposals into four categories: explanation using psycholinguistic models such as the Sausage Machine by Frazier and Fodor (1978), Bever's (1968) Canonical Sentoid Strategy; computational models such as the Deterministic Parser by Marcus (1980) or the Licensing model by Abney (1987), lexical models such as Ford, Bresnan and Kaplan (1982); and semantic/pragmatic accounts such as Crain and Steedman (1985). In addition, Pritchett has proposed a new approach to explaining garden path phenomena, which he calls a grammatical explanation. We do not go into details of these models here. (Pritchett, 1987, provides a review and critique of various proposals.) But here again, Japanese can be used to test the validity of these models.

## 2. Material

There has been little literature on Japanese garden path phenomena. One possible reason is that intuitively, Japanese speakers do not seem to encounter particular constructions that cause consistent and severe processing difficulties comparable to English garden path sentences, such as "The horse raced past the barn fell." There are sentences that mislead Japanese speakers occasionally if they are not careful, but that is quite a distinct psycholinguistic experience from the consistent difficulty English speakers experience with some of the severe garden path sentences.

Theoretically, however, we can construct sentences that are possibly garden path based on processing models proposed for English. Based on Snyder (1987), three types of possible garden path sentences were constructed.

### a. Particle garden path sentences

The first class of possible garden path sentences in Japanese involves consecutive NPs that are marked with particles such that they can belong to a single clause, as shown in (15).

#### (15) Particle Garden Path Sentences

a. Kazuko ni Yuuzi o saiyou-sita kaisha ga mensetu o  
 name D name A employed company N interview A  
 si tai to itte kita  
 want-to-do that notified

\* [e Kazuko ni Yuuzi o...]  
 [e Kazuko ni [e Yuuzi o saiyou-sita] kaisha ga...  
 "The company which hired Yuji contacted Kazuko for an interview"

b. Tanaka ni Yasuko o intabyuu sita kisyā ga ai  
 name D name A interview did reporter N came  
 ni kita  
 to meet

\* [e Tanaka ni Yasuko o...]  
 [e Tanaka ni [e Yasuko o intabyuu sita] kisyā ga...  
 "The reporter who interviewed Yasuko came to see Tanaka"

c. Hahaoya ga musuko ni te o yaita tannin no kyoosi  
 mother N son D be troubled class-teacher  
 ni yobidasareta  
 D called for P

\* [Hahaoya ga musuko ni te o yaita]...  
 [Hahaoya ga [e musuko ni te o yaita] tannin no kyoosi ni...  
 "The mother was called for by the class teacher who was troubled by the son"

d. Tatuko ga Hiromi ni sikarareta kodomo o kawaiiso da  
 name N name D scolded child A pitiful C  
 to omotta  
 that thought

\* [Tatuko ga Hiromi ni sikarareta]...  
 [Tatuko ga [e Hiromi ni sikarareta] kodomo o...  
 "Tatsuko felt sorry for the child who was scolded by Hiromi"

e. Roozin ga kodomo o yonda zyosee to hanasi o sita  
 old man N child A called woman with talk A did

\* [Roozin ga kodomo o yonda]...  
 [Roozin ga [e kodomo o yonda] zyosee to...  
 "The old man talked to the woman who called the child"

We call these particle garden path sentences. (15) a and b have two NPs that are marked with the Dative marker and the Accusative marker, respectively. As it is possible for the two NPs to be part of a simple clause, and there is no indication they might be otherwise at this point, we may be lead down a garden path. When the verb is encountered, however, it becomes obvious that the dative noun must not be an argument since this verb cannot take a dative NP. Similarly, (15) c, d and e involve two or three NPs that can be analyzed as part of a simple clause. These sentences, however, are forced to be reanalyzed not by the embedded verb, as they can take all of the previous NPs as arguments, but by the noun following the verb, which turns out to be the head of a relative clause requiring the subject position of the embedded clause to be empty.

Although we did not include them in the present experiment, the point of disambiguation which forces misanalysis can be delayed by embedding these relative clauses more deeply.

#### b. Kureru garden path sentences

The second class of garden path sentences involves the verb kureru. This is one of a set of verbs for giving and receiving, and specifically means that somebody else gave something to the speaker. When it is used as a compound verb, it means somebody did something for the speaker.

Sentences (16) a-e all have embedded clauses which can take the first NP as their subject.

(16) Kureru garden path sentences

a. Itoko ga piano no happyooka de Bahha o hiita  
 name N piano G performance L Bach A played

toki hanataba o motte kiki ni kite kureta.  
 when bouquet A bring came to listen

\*[Itoko ga piano no happyookai de Bahha o hiita ] toki  
 [Itoko ga [e piano no happyookai de Bahha o hiita ] toki...

"When I played Bach at the piano performance, Itoko came to listen to it with a bouquet."

b.

Yuuzin ga moochoo de nyuuin siteita toki mimai ni  
 friend N appendicitis due to was hospitalized when came to  
 kite kureta.

visit

\*[Yuuzin ga moochoo de nyuuin siteita] toki...

[Yuuzin ga [e moochoo de nyuuin siteita ] toki...

"When I was hospitalized because of appendicitis, a friend came to visit me

c. Tsuma ga sigoto de tetsuya o sita node  
 wife N work due to staying up all night A did because

sasiire o motte kite kureta.

food A brought

\*[Tsuma ga sigoto de tetsuya o sita ] node...

[Tsuma ga [e sigoto de tetsuya o sita ] node...

"Because I stayed up all night to work, my wife brought some food"

d. Itoko ga kaze o hiite neteita toki okayu o  
 name N cold A had was in bed when gruel A

taite motte kite kureta

cook brought

\*[Itoko ga kaze o hiite neteita] toki...

[Itoko ga [e kaze o hiite neteita] toki...

"When I caught a cold and stayed in bed, Itoko came to bring some gruel."

e. Hukuda ga buchoo ni sikararete otikonde ita toki  
 name N section head D criticized-P was depressed when

nagusamate kureta.

comforted

\*[Hukuda ga buchoo ni sikararete otikonde ita] toki...

[Hukuda ga [e buchoo ni sikararete otikonde ita] toki...

"When I was depressed because I was criticized by the section head, Fukuda comforted me."

But when they are followed by a matrix verb that contains kureru, the reader has to reanalyze the sentence initial NP as the subject of the higher clause verb. It is possible to conclude that the subject of the higher clause is null and that the sentence initial NP is a subject of the embedded clause. However, without a strong context, such an interpretation is highly unlikely and the sentences in (16), when presented alone, usually force the reader to take the former interpretation.

c. Coordinated relative sentences

The last class of possible garden path sentences in Japanese involves relative clauses that are stacked consecutively to modify a noun. In (17)d for example, onnanoko (girl), is modified by two relative clauses [e naiteiru] (crying) and [e akanboo o obutta] (carrying a baby). However, on the surface, the first noun in the second relative clause may be taken as the head noun of the first relative clause, being misanalyzed as "[e naiteiru] akanboo" (crying baby).

(17) Coordinated Relative Garden Path Sentences

a. Titioya ga katte kita miruku o yoku nomu  
 father N bought milk A well drink  
 marutiizu no koinu ga omorasi o sita.  
 Maltese G puppy N peed accidentally  
 \*[[Titioya ga e katte kita] miruku o yoku nomu] marutiizu no  
 koinu ga...  
 [[Titioya ga e katte kita] [e miruku o yoku nomu]] marutiizu no  
 koinu ga...

"The Maltese puppy the father bought, and which drinks lots of milk, peed accidentally."

b. Butyoo ga kaita konpuutaa puroguramu no yoona  
 Section head N wrote computer program G like  
 memo ga kakuka ni mawatte kita.  
 memo N each section D was circulated  
 \*[[Butyoo ga e kaita] konpuutaa puroguramu no yoona] memo ga...  
 [[Butyoo ga e kaita] [konpuutaa puroguramu no yoona]]memo ga...  
 "The memo the section head wrote, which looks like a computer program, was  
 circulated to each section"

c. Tyoonan ga kayotte iru daigaku yori hairu no ga  
 son N goes to College harder than enter that N  
 muzukasii to iu yobikoo de hahaoya ga zyukun sidoo  
 difficult said that school L mother N exam advice  
 o uketa  
 A took

\*[[Tyoonan ga e kayotte iru] daigaku yori hairu no ga  
 muzukasii to iu] yobikoo de  
 [[Tyoonan ga e kayotte iru] [e daigaku yori hairu no ga  
 muzukasii to iu]] yobikoo de

"The mother go some exam advice at the special tutoring school where her  
 son goes, which is said to be even harder to get into than college."

d. Naiteiru akanboo o obutta onnanoko o wakai otoko  
 Crying baby A carrying girl A young man  
 ga naki-yamaseyoo to hissi datta.  
 N try to make stop crying desperate was

\*[[[e Naiteiru] akanboo o obutta ] onnanoko o...  
 [[e Naiteiru] [e akanboo o obutta ] onnanoko o...]

"A young man was trying desperately to stop the girl, who was carrying the  
 baby, from crying"



e. Kaidan de kega o sita kodomo o daite ita  
 stairs L injury A did child A was holding  
 onna no hito ga kyuukyusha de byooin e hakobareta.  
 woman N ambulance I hospital L was carried-P  
 \*[[e Kaidan de kega o sita] kodomo o daite ita] onna no hito  
 [[e Kaidan de kega o sita] [e kodomo o daite ita]] onna no hito  
 "The woman who was injured on the stairs, and who was holding a child, was  
 taken to the hospital in an ambulance."

Syntactically, these types of sentences are ambiguous, as the latter analysis does not result in ungrammaticality. Semantically, however, the sentences are constructed such that the nested relative interpretation is not plausible. For example, the main clause of (17) d means "the young man desperately tried to make the girl stop crying." Unless it was the girl who was crying (and not the baby), the main clause does not make sense.

### 3. Results and discussion

Figure 5 shows the reading time per character for each type of garden path sentence and control sentence. Figure 6 shows the reading time per mora for the same sentences.

In addition, in order to test how the subjects interpreted these sentences, 4 of the kureru type sentences and 4 of the coordinate relative sentences were followed with true/false judgement sentences. For the kureru sentences, subjects correctly judged that the first noun was not the subject of the embedded clauses 49 times (78%). For the coordinate relative sentences, on the other hand, subjects incorrectly stated that the simple sentence indicated a nested relative interpretation 76% of the time (55 out of 72), e.g., "akanboo ga naiteita" (baby was crying). Post-experiment interviews revealed that when the subjects were asked to think about the sentence, most of them took the coordinate relative interpretation. However, some of them needed an explanation of such an interpretation before they could understand it.

Intuitively, particle garden path sentences occasionally lead us down a garden path, making us consciously reanalyze. Otherwise, they tend to give us an impression of general difficulty similar to degree 1 center-embedded sentences. Kureru sentences, on the contrary, do not give an impression of difficulty, but seem to make us consciously reanalyze them relatively more frequently. Neither of these are, however, as severe or consistent as English garden path sentences. The coordinate relative sentences are a little different from the other two. The first impression is usually that the sentence does not quite make sense although we can understand it somehow. The coordinate relative interpretation rarely seems to be available to the reader. Once the reader realizes that the coordinate relative interpretation is possible, however, the sentence becomes quite clear.

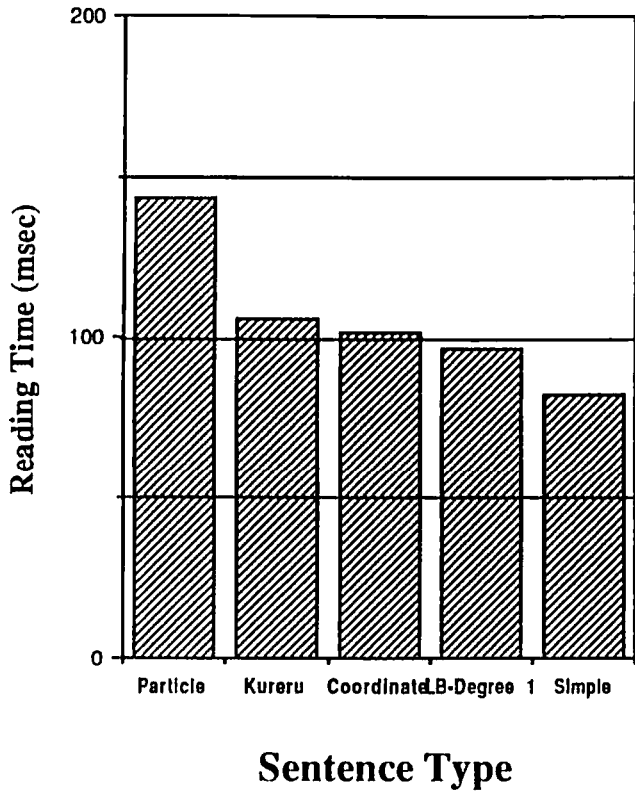


Fig. 5 Reading Time per Character for Garden Path Sentences

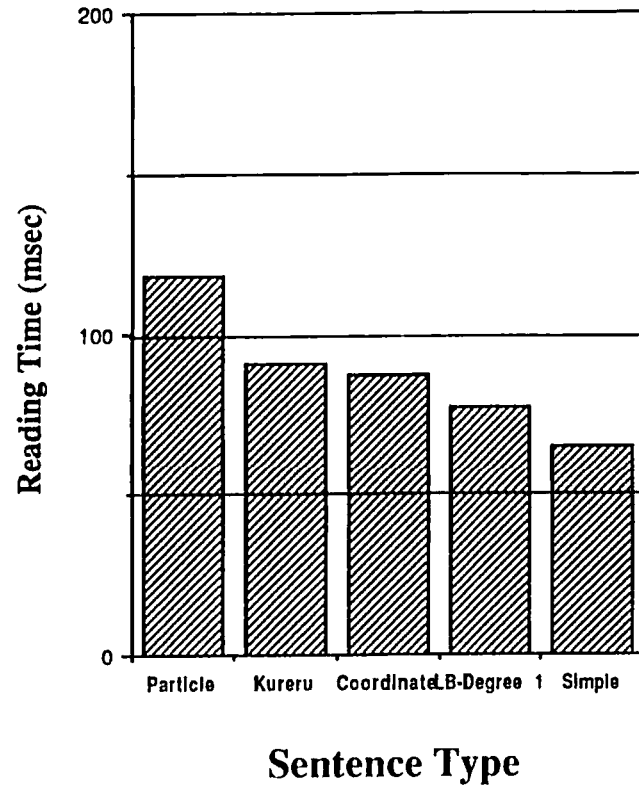


Fig. 6 Reading Time per Mora for Garden Path Sentences

Experimentally, the results from the coordinate relative sentences indicate that Japanese readers have a strong tendency to prefer nested left branching structures to coordinate relative structures even when the former are semantically incongruous. Since the subjects apparently took the sentences as nested left branching structures, which did not require reanalysis, their reading time should have reflected their interpretation as such. The fact that the reading time was not longer than for the control sentences is consistent with this interpretation. In English, Rayner, Carlson and Frazier (1983) found that when the syntactically preferred analysis did not cohere with semantic and pragmatic plausibility, subjects took longer to read the sentence. In the current experiment, subjects did not even notice that there was an alternative structure. Thus, it is possible that if they had different instructions to read more carefully, they would have taken longer to read these sentences.

Particle garden path sentences took longer to read than the other sentences, including the kureru sentences. The reading time for this type of sentence was almost the same as degree 1 center-embedded sentences. In contrast, kureru garden path sentences did not take longer to read than control sentences.

Strategies such as Minimal Attachment (Frazier & Fodor, 1978; Frazier & Rayner, 1988) predict that particle garden path sentences should indeed be garden path sentences. However, if reanalysis in these sentences causes an increase in reading time, then it is not obvious why the kureru sentences, which are also predicted to have undergone reanalysis, did not have an increased reading time.

Alternatively, Pritchett predicts that none of the possible garden path sentences we tested are true garden path sentences. He considers that sentences with global ambiguity are not garden path sentences. Thus, our kureru sentences and coordinate relative sentences are not garden path sentences for him. All of our particle garden path sentences involve relative clauses. Thus, it is the head noun that causes reanalysis. According to Pritchett's proposal, garden path phenomena should occur only when reanalysis involves taking an argument which is already assigned a theta role out of that theta domain, and re-assigning a new theta role to it. When what forces the reanalysis does not assign a theta role, a garden path should not result. The head noun of relative clauses is not a theta role assigner, thus the particle garden path sentences we constructed should not be garden path sentences according to Pritchett.

Considering that none of the possible garden path sentences in Japanese cause the consistent and severe garden path phenomena observed in English, this is a viable possibility. If we take this view, and consider none of these sentences to be garden path, then the longer reading time for particle garden path sentences in the present experiment need to be explained.

The fact that the reading times for particle garden path sentences were almost the same as for the degree 1 center-embedded sentences may indicate that overt animate NPs stacked consecutively may add to the processing load. As mentioned above, center-embedded Japanese sentences become easily processible when the overt NPs are dropped. The particle garden path sentences also give the impression that the sentences are easier to comprehend when the overt NPs are dropped. (These sentences are not "possibly garden path" any longer. Note that when the NPs are dropped, these sentences become indistinguishable from center-embedded sentences with NPs dropped.)

Abe, Hatasa and Cowan (1986) tested the comprehension and reaction time for various relative clauses in Japanese and found that degree 1 center-embedded sentences caused similar processing difficulties to what we here call particle garden path sentences.

The control sentences in the current experiment cannot rule out this possibility since they had only one animate NP in a clause, but it is simple to test this prediction experimentally.

This explanation implies that the occasional intuition for misanalysis for these sentences is not reflected in the overall reading time. Further analysis of the data, such as reading time for parts of sentences, fixation point and regressive eye movement may enable us to identify other aspects of eye movement during reading that reflect the reanalysis of garden path sentences.

## Multiply-Left-Embedded Sentences

### 1. Background

In the English psycholinguistic literature, left branching structures are often reported to be harder to process than their right branching counterparts (see Frazier & Rayner, 1988; Mazuka & Lust, to appear, for discussion). In a predominantly right branching language such as English, left branching structures are usually more marked, and have a more complex structure. Thus, it is not surprising that such structures cause some processing difficulty. However, in a predominantly left branching language such as Japanese, it is not likely that left branching structures will cause processing difficulty.

When a structure is left branching, backward anaphora as well as forward anaphora can occur. It is sometimes argued that the difficulty associated with left branching structures in English is due to the presence of backward anaphora (Frazier & Rayner, 1988), indicating that backward anaphora is a source of processing difficulty. However, in a left branching language, like Japanese, backward anaphora is very productive, and does not give an intuitive impression of processing difficulty.

## 2. Material

In this study, five sentences with multiply-left-embedded clauses, as shown in (18) a-e, and multiply-left-embedded sentences with long-distance backward anaphora as in (19) a-e were constructed.

(18) Without long distance backward anaphora

a. [[[ Byooki bakari siteiru] Takako no koto o  
 sick always was name G fact A  
 arekore to sinpai siteita] hahaoya ga nakunatta].  
 this-and-that worrying mother N passed away  
 "The mother who was worried about Takako who has been always sick died."

b.

[[[ Boonasu o moratta] bakari no otto ga katte kita]  
 bonus A received recently G husband N bought  
 zairyoo de Akiko ga yuusyoku ni gotisoo o tukutta]  
 ingredients I name N dinner for feast A cooked  
 "Akiko cooked a delicious dinner with the ingredients that her husband who just got a bonus bought."

c.

[[[Nyuusha sita] bakari no Yamasita no kenkyuu ga  
 newly employed G name G research N  
 zyoosi ni mitomerareta koto ga kosan no kenkyuusha tati  
 superior D was recognized that N old G researchers  
 no sinkee o sakanade sita]  
 G nerve A rubbed in a wrong way  
 "The fact that Yamashita's research, who just entered the company, was recognized by the superiors upset the older researchers."

d. [[[ Turikyaku o noseta] hune o sensuikan ga  
 fishing tourists A carried boat A submarine N  
 tinbotu saseta ziken ga masukomi ni. daidai teki ni  
 sink made accident N media D sensationally  
 toriage rareta  
 was covered-PASS

"The media sensationally covered the accident that the submarine sank the boat which was carrying fishing tourists"

e.

[[[ Sohu no hatake de toreta] yasai o tukatte  
 grandfather G garden L grew vegetables A used  
 tukutta] sinsen na sarada o kodomotati ga yorokonde  
 made fresh salad A children N gladly  
 tabeta]  
 ate

"Children happily ate the fresh salad which is made with the vegetables from the grandfather's garden."

(19) With longdistance backward anaphora

a. [[[[[e Nakusita] to omotte] iezyuu o sagasite ita]  
 lost that thought house A searching  
 pen o ototoo ga motte ita] koto ni kizuita] Hiroshi ga  
 pen A brother N had fact that noticed name  
 gekido sita]  
 was furious

"Hiroshi got furious when he found out that his brother had the pen he was looking for throughout the whole house because he thought he had lost it."

b. [[e Oogata kansetuzei ni teikoo suru] koto ga senkyo  
 big sales tax D resist do fact N election  
 de no syoori ni tunagaru] to zen yattoo ga  
 L G victory D lead to that all opposing parties N  
 kangaeteirur].  
 are thinking

"All opposing parties are thinking that resisting the big sales tax will lead to victory in the election."

c.

[[[e Kinoo kaita] puroguramu o atarasii konpuutaa  
 yesterday wrote program A new computer  
 de tamesiteita] Suzuki ga misu o hakken sita]  
 I was testing name N mistake A discovery did

"Suzuki found a mistake in the computer program he wrote yesterday when he was testing it with the new computer."

d. [[e Sikika ni atta] buka ga syuuwaizai ni  
 supervision L was subordinate N bribery  
 towareta] sekinin o totte] buchoo ga zinin sita]  
 charged responsibility A took section head N resigned

"The section head resigned taking the responsibility of the subordinate who was under his supervision, and was charged with bribery."

e. [[[e Roonin site demo hairi tai] to omotte ita]  
 \* even enter-wish that thought  
 daigaku ni kotosi mo hugookaku datta] koto ga  
 university D this year also not accepted fact N  
 Mamoru o zetuboo saseta.  
 name A lost hope made

(\* take an extra year preparing for the next year's entrance examination)

"The fact that Mamoru was once again not accepted by the university he wished to enter even after an extra year's preparation made him lose hope."

(18) a-e involved two degrees of leftward embedding, with local backward anaphora when the embedded clause was a relative clause. (19) a involved 5 levels of embedding. The antecedent of the null subject of the most deeply embedded clause [e nakusita] "e lost" was "Hiroshi" which was the subject of the main clause. Similarly, (19) b, c and e had null subjects in the deepest clause, and their antecedents were main clause subjects. In (19) d the gap was in the genitive position of a predicate noun. (19) b and c had two levels of embedding; d had three; and e had four.

### 3. Results and discussion

Figures 7 and 8 show the reading time per character and the reading time per mora for these sentences respectively. The results show that the multiply-left-embedded sentences were no more difficult than the control sentences. Sentences without the long-distance backward anaphora took even less time than the control sentences. Sentences with the long-distance anaphora took slightly longer than the sentences without anaphora, but this may have been due to the former sentences having generally more levels of embedding.

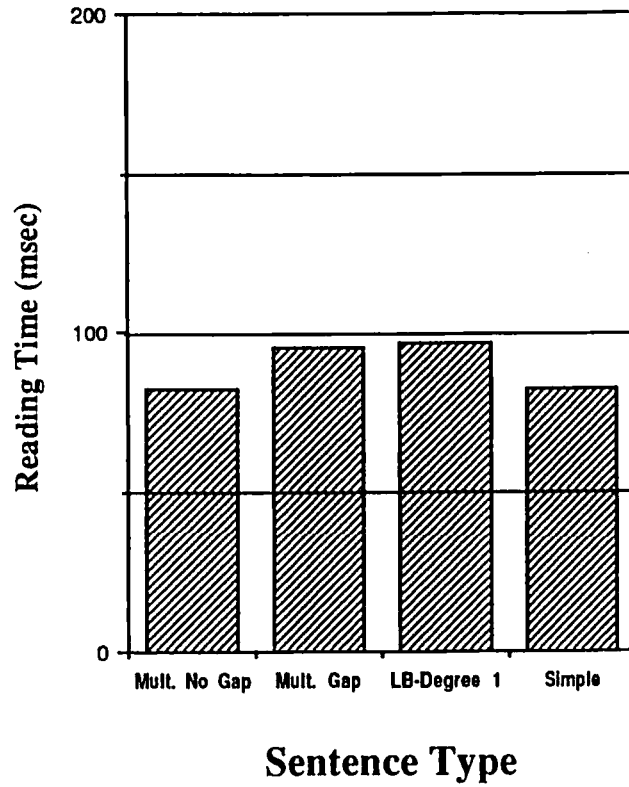


Fig. 7 Reading Time per Character for Left-Branching Sentences

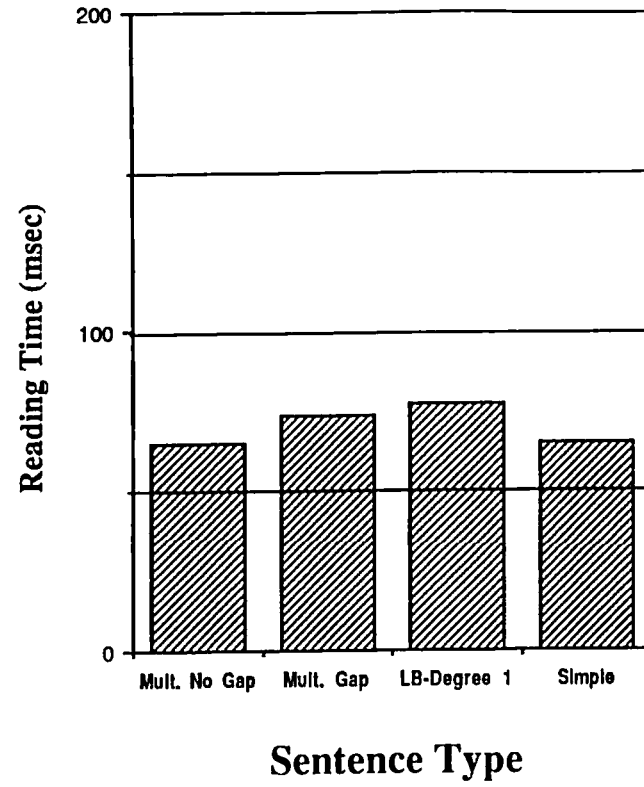


Fig. 8 Reading Time per Mora for Left-Branching Sentences

The results clearly support Japanese native speaker intuitions that left branching structures, even when there are multiple levels of embedding, do not cause processing difficulty. They also show that the presence of backward anaphora, even when it is over a long distance, does not pose serious difficulty for a Japanese reader.

## Discussion

It was found that Japanese center-embedded sentences, especially when the degree of embedding was 2, caused processing difficulties comparable to English. Thus, it seems reasonable to assume that whatever is causing this processing difficulty is universal. On the other hand, multiply-left-branching sentences, which are often reported to be harder to process than right branching structures in English, did not cause processing difficulty. The presence of long-distance backward anaphora did not seem to make these sentences harder than control sentences. In this aspect, Japanese and English appear to differ. The explanation for the left branching difficulty in English, therefore, must be able to predict that such difficulty will not occur in left branching languages such as Japanese.

The results from the garden path sentences indicate that in Japanese garden path phenomena in the strict sense, which in English involves consistent and severe processing difficulty, may not exist. It was not clear that the longer reading times for the particle type garden path sentences were due to misanalysis or to the mere existence of consecutive NPs, since degree 1 center-embedded sentences that did not force a misanalysis resulted in similar reading times. If English garden path phenomena are an outcome of the combination of reanalysis plus some additional complications, such as theta role reassignment, as proposed by Pritchett, and if these two factors do not occur simultaneously in Japanese, then the apparent lack of severe Japanese garden path sentences, and the ease of reanalysis in kureru sentences, may be explained.

One crucial property of Japanese processing which became obvious from the present study is the processing of empty categories. All of the garden path sentences considered in the present study were made possible by the presence of optional empty categories. If we assume that the ultimate outcome of our sentence comprehension is some form of propositional representation, then we must posit empty categories for dropped arguments in languages such as Japanese. If we are to posit empty categories, we must first identify their presence (or need). Then we must decide where they should be located, and compute what they should be referring to, all in real time. It seems logical, then, that empty categories involve more complex processing than overt NPs. However, as we discussed above, even without any discourse or pragmatic information, dropping overt NPs will make sentences easier to comprehend. Since English does not allow productive



empty categories, their processing has not been explored thoroughly. However, as they play a crucial in processing languages such as Japanese, they should be investigated further.

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