Reading Times and Priming Effects in Japanese Scrambled Sentences

Tohoku Psychologica Folia
2004, **63**, 84－94

Reading Times and Priming Effects in Japanese Scrambled Sentences

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The present study investigates whether or not "a trace", which is linguistically hypothesized to be left behind by syntactic movement, is mentally created when a scrambled sentence in Japanese is processed. From past to present, the result of a self-paced reading experiment has supported the psychological reality of trace, but the result of a probe recognition task has indicated otherwise. To accommodate those apparently conflicting results, we suggest a model of processing, according to which syntactic processing and storage of lexical information compete against each other for the limited resources of verbal working memory.

Key words: antecedent reactivation, probe recognition, scrambling, trace, working memory

Introduction

Scrambling in Japanese

It is a well known fact that word order in Japanese is flexible: the verb must come at the end of the sentence, but the order of the other phrases is comparatively free. For instance, whereas the canonical order in Japanese transitive sentence is SOV, noncanonical OSV order is also possible, as exemplified in (1) below (*-ga*: nominative case marker; *-o*: accusative case marker). According to the most widely held view within theoretical linguistics (Chomsky, 1981, 1995), the OSV order in (1b) is derived from a structure similar to (1a), by moving the accusative object *seito-o* to the sentence initial position (Saito, 1985). This type of syntactic movement is called "scrambling," and sentences involving scrambling are called "scrambled sentences."

(1) Transitive sentences

a. Canonical order: [NP-ga NP-o V]

Sensei-ga	seito-o	mita.
teacher-Nom	student-Acc	saw

'The teacher looked at his student.'

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b. Noncanonical (scrambled) order: [NP-o NP-ga V]
Seito-o sensei-ga mita.
student-Acc teacher-Nom saw

Scrambling, as any other type of syntactic movement, is assumed to leave behind a phonetically empty category, "trace" (indicated here as *t*), in its original position, and the moved item is grammatically associated with it. Thus, the examples in (1) are standardly assumed to have structures like those in (2). (S: sentence; VP: verb phrase)

(2) a. $[_S$ sensei-ga $[_{VP}$ seito-o mita]]
teacher-Nom student-Acc saw
b. $[_S$ seito-o_1 $[_S$ sensei-ga $[_{VP}$ t_1 mita]]]
student-Acc teacher-Nom saw

In terms of sentence processing, scrambled sentences involve a filler-gap dependency, with the moved item being the filler, and the trace being the gap.

Sentences with a ditransitive verb involve with any of the six logically possible orders among the three arguments of the verb. This is schematically shown in (3). Of these six orders, (3a) is the canonical order, and the remaining five are derived by one or more application of scrambling (Hoji, 1985). (*-ni*: dative marker)

(3) Ditransitive sentences
a. Canonical order: [NP-ga NP-ni NP-o V]
b. Scrambled orders: [NP-ga NP-o_1 NP-ni t_1 V]
[NP-o_1 NP-ga NP-ni t_1 V]
[NP-ni_1 NP-ga t_1 NP-o V]
[NP-ni_1 NP-o_2 NP-ga t_1 t_2 V]
[NP-o_2 NP-ni_1 NP-ga t_1 t_2 V]

Japanese also has "long-distance scrambling," a scrambling across a clause boundary, as shown in (4) and (5). (*-to*: complementizer)

(4) Long-distance scrambling
a. Canonical Sentence
[NP-ga [NP-ga NP-o V-to] V]
b. Scrambled Sentence
[NP-o_1 NP-ga [NP-ga t_1 V-to] V]

(5) a. [Taro-ga [Hanako-ga sono hon-o yonda-to] itta]
Taro-Nom Hanako-Nom that book-Acc read Comp said

b.	[sono hon-o$_1$	[Taro-ga	[Hanako-ga	t_1	yonda-to]	itta]]
	that book-Acc	Taro-Nom	Hanako-Nom		read Comp	said

In the "long-distance scrambling", the accusative NP '*sono hon-o*' in (5b) leaves its trace behind at the object position of the embedded sentence and moves to the sentence initial position, crossing a clause boundary created between the matrix clause and the embedded clause. This fact indicates that Japanese scrambling is not limited in clause-internal operation.

Reading times of scrambled sentences

If scrambled sentences generally have more complex syntactic structures than their canonical counterparts as hypothesized in theoretical linguistics, and if these structures are computed during online processing, comprehension processes of scrambled sentences should be more complicated than that of canonical sentences. To investigate whether or not this expectation is fulfilled, psycholinguistic experiments thus far have been conducting measurement of reading times (and error rates). For example, using a sentence plausibility judgment task with visually presenting a whole sentence on a screen at once, Chujo (1983) and Tamaoka, Sakai, Kawahara, Lim and Miyaoka (2003) observed longer reading times and higher error rates for scrambled transitive sentences like (1b), compared to canonical transitive sentences like (1a). Another study, using a moving-widow self-paced reading paradigm, which can measure participants' reading times of each phrase, Nakayama (1995) reported that the average reading time of the subject arguments in scrambled sentences were longer than that of canonical sentences.

Similarly, Miyamoto and Takahashi (2002a) and Koizumi and Tamaoka (2004) observed that participants took longer time in reading scrambled ditransitive sentences than canonical ditransitive sentences. Yamashita (1997) did not find any differences in reading time between canonical and scrambled ditransitive sentences. However, as pointed out in Miyamoto and Takahashi (2002a) and Tamaoka et al. (2003), the items in her experiment were inappropriate for the self-paced paradigm used in her study because 1) they were rather simple and might have been read at a constant pace in all conditions, and 2) they were not controlled in terms of the number of symbols (or letters) and morae for comparison.

In addition to reading times, Mazuka, Ito and Kondo (2002) investigated off-line intuitive judgments of difficulty and misleadingness on canonical and scrambled sentences, and also participant's eye-movement while reading those sentences. Their results indicate that the processing of scrambled sentences is more difficult than that of canonical sentences.

In sum, previous psycholinguistic studies have shown that scrambled sentences are more difficult to process than their canonically ordered counterparts. This is consistent with the theoretical linguistic account that scrambled sentences have more complex syntactic structures than canonical sentences: scrambled sentences contain a trace, which is particularly absent in canonical sentences. If a trace is mentally represented during online processing (and if human sentence processing is incremental, as standardly assumed), a trace must be created immediately after the parser's reading of the subject phrase during processing of a scrambled transitive sentence like (1b) for instance. The longer reading times for scrambled sentences must be a reflection of the extra load to working memory caused by this process (Nakayama, 1995;

Miyamoto & Takahashi, 2002a; Nakano, Felser & Clahsen, 2002).

Priming effect of a trace in Japanese scrambled sentences

In order to investigate whether or not a trace is mentally represented during sentence comprehension, a method of priming effect has frequently been used. "Priming" generally refers to the facilitated effect of the precedent stimulus. For example, immediately after reading or hearing certain words, recognition of those words is generally faster than other words because the activation level of those words are thought to have increased in the brain.

The probe recognition task is a well-known task often used for investigating the priming effect in various languages (e.g. Bever and McElree 1988). In Japanese, Nakayama (1995) and Miyamoto and Takahashi (2002b) used the task to examine the activation level of the trace of a scrambled argument. In their task, participants were shown a probe word immediately after reading a sentence, and were asked to decide as quickly as possible whether or not the probe word had appeared in the sentence. The probe was chosen from the moved phrase in the case of the scrambled condition. Consider the examples in (6), which are much simplified for the sake of exposition (see (7) below for examples actually used in their work).

(6) a. Canonical sentence (the probe word (*seito*) is activated once):
Seito-ga sensei-o mita.
teacher-Nom student-Acc looked
'The student looked at the teacher.'

b. Noncanonical (scrambled) sentence (the probe word (*seito*) is activated twice):
Seito-o sensei-ga t mita.
student-Acc teacher-Nom looked
'The teacher looked at the student.'

The probed word in the canonical sentence is thought to be activated only once, whereas the probed word in the scrambled sentence is expected to be activated twice, once at the fronted object position and once at the trace position. Therefore, if the trace is actually represented in the brain during online processing, the activation level of the probe word should be higher after scrambled sentences than after canonical sentences, and the scrambled sentences should evoke faster response times than canonical sentences.

Nakayama (1995) compared canonical and scrambled sentences, and reported that the predicted facilitation was not observed in the scrambled sentences. Miyamoto and Takahashi (2002b), however, claimed that Nakayama's experiments were inappropriate in that recency effect and temporary ambiguity were not controlled. They pointed out that the probed word in Nakayama's experiment is closer to the end of the sentence in canonical condition (i.e., recency effect is uncontrolled), and the canonical sentences in his experiments involve with a process of reanalysis (i.e., temporary ambiguity is involved). Miyamoto and Takahashi (2002b) found the reactivation effect in the scrambled condition, by modifying Nakayama's items in terms of his inappropriate factors and comparing the probe recognition times in the canonical and scrambled conditions. Nakano, Felser and Clahsen (2002), using a cross-modal lexical priming task, also observed that the priming effect of long-distance scrambling is confirmed when the participant's working memory capacity is relatively large.

The purpose of the present experiment

As we have seen, reading times and priming effects are important measures to investigate the complexity of scrambled sentences. However, there are few studies that compared Japanese canonical sentences with scrambled sentences on the two measures at once. Nakayama (1995) measured the reading times and priming effects with the same sentences, but as mentioned above, his study was criticized for the materials used in his experiments. Miyamoto and Takahashi (2002b) also investigated both measurements but the results of the reading times were not reported in their paper (according to a personal communication, there was no significant difference in reading time between the two conditions). Since the increased reading times and the increased priming effects (as reflected in shorter response times to probe words) are concurrently hypothesized to be caused by the same factor, (i.e. the syntactic complexity due to the presence of a trace in the scrambled sentences), there should be some relation between them. More specifically, longer reading times and shorter probe recognition times should be observed for the same set of scrambled sentences. Thus, we conducted an experiment to test this prediction.

Method

This experiment is basically a retest of Miyamoto and Takahashi (2002b) so that the present material and procedure are mostly the same as theirs.

Participants

Twenty-six students from Tohoku University were paid to participate in the experiment.

Materials

We used the same test items as used in Miyamoto and Takahashi's (2002b) Experiment 3[3]. They prepared twenty pairs of sentences like those in (7). All the test sentences consist of seven phrases or Japanese *bunsetsu* (from B1 to B7). The two sentences in each pair have the same content words in the same order. Only difference between the two sentences is the order of the italicized nominative and accusative case markers. The case marker of the forth phrase is nominative in the canonical condition and accusative in the scrambled condition, and the sixth phrase is accusative in the canonical condition and nominative in the scrambled condition. The word in the second phrase (e.g. *mondai* in (7)) was used as the probe.

3. Edson T. Miyamoto and Shoichi Takahashi kindly provided us with their test items, for which we are grateful.

(7) a. Canonical condition

B1	B2	B3	B4	B5	B6	B7
Gakkoo-de	mondai-o	dashita	kooshi-*ga*	mukuchina	gakusei-*o*	mita.
school-at	question-ACC	asked	lecture-NOM	quiet	student-ACC	saw

'The lecture who asked the question at school saw the quiet student.'

b. Scrambled condition

Gakkoo-de	mondai-o	dashita	kooshi-*o*	mukuchina	gakusei-*ga*	mita.
school-at	question- ACC	asked	lecturer- ACC	quiet	student-NOM	saw.

'The quiet student saw the lecturer who asked the question at school.'

Using a Latin Square design, the sentences were distributed to create two lists. The test items were intermixed with 40 filler sentences, and the resulting 60 sentences were presented in random order. All sentences were written in commonly used Japanese characters (*kanji, hiragana and katakana*) (see Figure 1). The filler sentences and the comprehension questions following the test items used in the present experiment were different from those of Miyamoto and Takahashi (2002b).

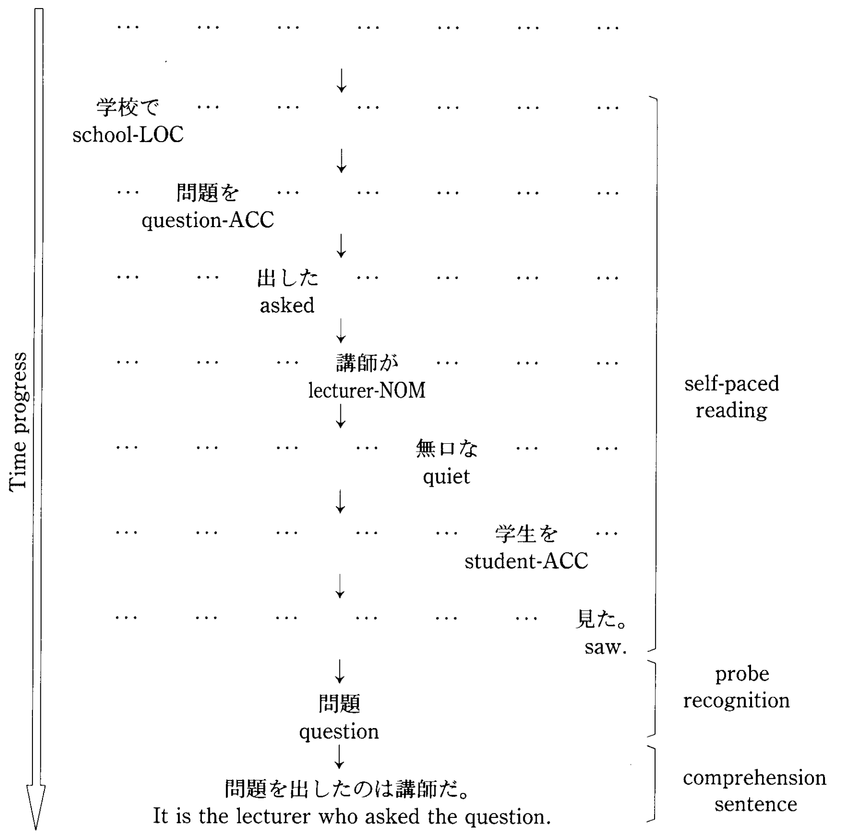

Figure 1. The procedure of the probe recognition task in this experiment.

Procedure

The experiment was controlled with a computer (SHARP X68000). Participants were timed in a phrase-by-phrase self-paced non-cumulative moving-window reading task (Just, Carpenter, & Woolley, 1982). An example of the moving window in the present experiment is shown in Figure 1. At first, a line of dots is presented on the screen. By pressing the space key on the keyboard, the first phrase, *Gakkoo-de*, appears on the computer screen, and by pushing the space key again, the first phrase returns to dots and the second phrase, *mondai-o*, appears. Repeating this procedure, participants read all phrases.

Immediately after the last phrase, *mita*, was read, a probe word, *mondai*, appears on the screen. The participants were asked to decide whether or not the probe word was included in the previous sentence by pressing the left click of a mouse for "Yes", and right click for "No". The participants were also instructed to click as quickly and accurately as possible. The reaction time was also automatically recorded by the computer as the measurement of the priming effect for the probe word.

A comprehension question was presented to the participants in the end of each sentence. The participants were asked to decide whether or not the content of the comprehension question was appropriately corresponding with the test sentences by clicking the mouse like the above-mentioned procedure. After five practice trials, 60 experimental trials were conducted.

Data analysis

Analyses were conducted on reading times for each phrase, reaction times, accuracy in judging the probes, and accuracy in the comprehension test. Two participants' data were eliminated from the analyses, due to the low percentage accuracy in the comprehension test (50%) or extremely slow reaction times in the probe recognition task (more than 2000 msec in the scrambled condition). Only test sentences whose comprehension question and associated probe recognition question had been both correctly answered were used in the analyses of reading times. Extreme data were also eliminated (reading times less than 100 msec or longer than 3000 msec; reaction times to the probes less than 400 msec or longer than 3000 msec). After these treatments, the data (reading times and reaction times) outside of 2.5 standard deviations (SD) at both the high and low ranges were replaced with boundaries indicated by 2.5 standard deviations from the individual means of participants in each category. The following statistical tests were conducted separately for participant (F_1) and item (F_2) variability.

Results

Response accuracy

The percentages of correct probe recognition did not show significant difference between the canonical and scrambled conditions (canonical, 98.5%; scrambled, 98.3%; $F_S < 1$), neither accuracy on the comprehension test (canonical, 92.1%; scrambled, 92.9%; $F_S < 1$).

Reading times of each phrase

Mean reading times of each phrase were presented in Figure 2. An analysis of variance (ANOVA) revealed no significant differences between the two conditions at B1, B2, B3, B4 and

B5 ($F_S < 1.35$). At B6, the reading time was marginally longer for the scrambled condition than for the canonical condition in the participant analysis (F_1 (1,23) = 3.93, p = .060), and significantly longer in the item analysis (F_2 (1,19) = 5.60, $p < .05$). The reading time for the scrambled condition at B7 was significantly longer than that of the canonical condition in the participant analysis (F_1 (1,23) = 10.23, $p < .005$), and marginally longer in the item analysis (F_2 (1,19) = 3.80, p = .066).

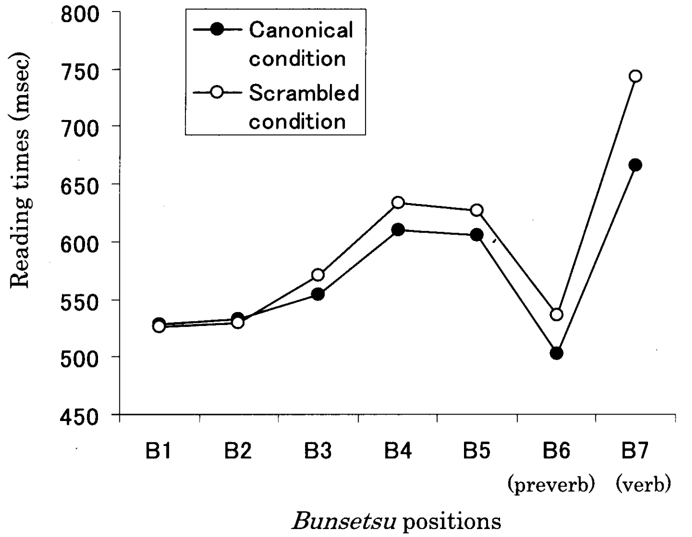

Figure 2. Mean reading times at each bunsetsu position. Bunsetsu is a content word plus inflectional material or functional particles.

Reaction times to the probe recognition task

The reaction time to the probe recognition task was significantly slower for the scrambled condition (991 msec) than for the canonical condition (922 msec) in the subject analysis (F_1 (1,23) = 8.07, $p < .01$) as well as in the item analysis (F_2 (1, 19) = 5.67, $p < .05$).

Discussion

In linguistic literature, scrambled OSV sentences are generally assumed to have more elaborate syntactic structure than their canonical counterparts due to the presence of a trace created by scrambling. This syntactic analysis has led us to the following two interrelated predictions prior to the experiment: 1) the reading times should be longer in the scrambled condition than the canonical condition, and 2) the reaction times to the probe recognition task should be shorter in the scrambled condition than the canonical condition. The results of our experiment show that the reading times were significantly longer in the scrambled sentences than the canonical sentences at the preverbal and verbal positions. These results are along in line with the first prediction. They furthermore indicate that the processing load increased at the preverbal position (B6), and more working memory resources are used during processing the preverbal and verbal phrases (B6 and B7). This supports the idea that Japanese parsers are incremental in the sense that they start constructing syntactic structure before they encounter the sentence final verb, just as the hypothesis that linguistic traces are mentally created during online processing. Since the preverbal position (B6) was the first point at which it became apparent to the participants that the object had been fronted, it is reasonable to assume that insertion of its trace began during processing B6 and completed during processing B7.

Let us now turn to the results of the probe recognition task. Unlike the results reported in Miyamoto and Takahashi (2002b), the participants in our experiment recognized the probe faster in the canonical sentence presentation than in the scrambled sentence presentation. Thus, our second expectation mentioned above was not fulfilled. This indicates that the psychological reality of the trace was supported from the results of the reading times but not from the results of the priming effects.

To account for these apparently conflicting results, we present a conceptual model (Figure.3) (Koizumi, 2003), which postulates the change of the activation level of the probed words, which are included in the subject phrase in a canonical sentences and in the object phrase in a scrambled sentence, during online reading. The solid line in this figure expresses the activation level of the probed word in the canonical sentences, and the dotted line signifies that in the scrambled sentences.

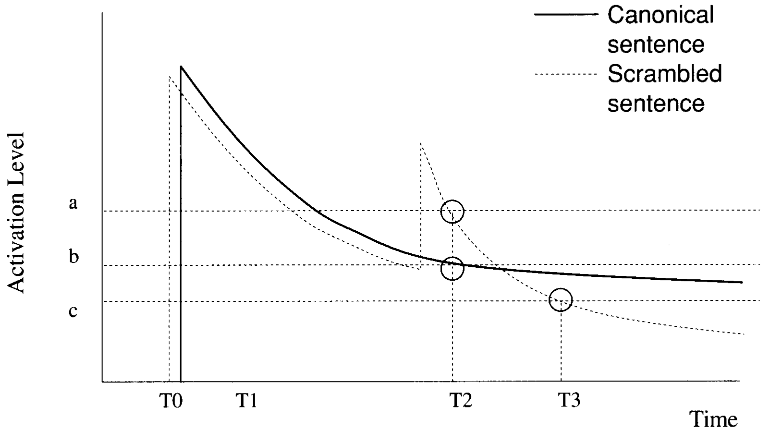

Figure 3. The conceptual model showing the change in the activation level of the probed word.

Let us first consider the change of the solid line. Although there are few experiments investigating in detail the magnitude of activation for the nominative phrase in the canonical sentences, it has been reported that the recency effect had a great influence in the probe recognition task (e.g. Nakayama, 1995), and that the significant difference of the priming effect is not observed in comparison of the preverbal position and the position 500msec before the preverbal position in canonical sentences (Nakano, Felser & Clahsen, 2002). Therefore, we expect that the activation level of a probed word increases at T0, where participants read the probed word, decreases gradually after the activation, and reaches to an asymptote.

Secondly, consider the change of the dotted line. Unlike the canonical sentences, it can be assumed that the activation of the object in the scrambled sentences occurs twice. Therefore, our expectation is that the activation level of the probed word increases at T0, decreases gradually after the activation like the canonical sentence case, increases again at T1 due to the reactivation by the trace, and decreases again. Here, the rate of declining after the reactivation by the trace is assumed to be faster than after the first activation. The reason for this assumption is because more complex processing is necessary to create a trace in the object position and to integrate the information of the fronted object in the trace position at the time of reactivation, requiring more load to working memory. Since the capacity (or resources) of the verbal working memory system is limited, faster decline of activation level should happen due to the less resources available for maintaining the activation level of the probed word, after the usage of certain amount of resources in syntactic processing. This conceptual model is consistent with the previously reported generalization that self-paced phrase-by-phrase reading times and lexical decision times both increase at points in a sentence where models of sentence processing predict an increased processing load (Caplan & Waters, 1999; and references cited there).

If these assumptions are valid, the reaction times in the probe recognition task may be dependent on the reading times. For example, if there is no difference in reading times between the two sentence types, and the probe is presented at T2 in Figure 2 in both conditions, the activation level at the presentation of the probe word would be higher in scrambled sentences than in canonical sentences, and the reaction time of the recognition task becomes faster in scrambled sentences. This prediction corresponds with the results in Miyamoto and Takahashi (2002b). However, as in the present results, if the reading times are longer in the scrambled sentences than in the canonical sentences, the time from the activation to the presentation of the probe should differ in the two conditions (in the present results, the difference in the reading times from the probed word at B2 to the verb at B7 is 170 msec, and the difference from the trace at B6 to the verb at B7 is 111 msec). In the case that the probe presentation in the canonical sentence condition is at an earlier point of time (T2), whereas that in the scrambled sentence condition is at a later point of time (T3), the activation level of the probed word in the canonical condition at the probe presentation is higher than that of scrambled condition, resulting in the faster reaction time of the probe recognition in the canonical condition.

The model just sketched above can account for the present results as well as the results reported in Miyamoto and Takahashi (2002b). Apparently conflicting results reported in other studies (e.g. Nakayama, 1995) may also be suitably explained with this model. However, our model is still a conceptual one and has not yet proved credibly by the experiment. To reveal the online processing of the scrambled sentences, it would be necessary to investigate the working memory load of the transition of time course during subject and object processing in canonical and scrambled sentences. This still is a task for a future research.

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(Received September 22, 2004)
(Accepted October 15, 2004)