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Filler-Gap Dependencies in the Processing of Scrambling in Japanese*

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Given native speakers' knowledge of grammar, two immediate questions arise in psycholinguistics. The first is how such knowledge is attained. The second question is how this knowledge is used to process linguistic input. The present paper investigates the latter question in the word-by-word processing of scrambling in Japanese.

Key words: sentence processing, Japanese, scrambling, parsing

1. Introduction

When reading a sentence, people do not have access to all its words at once, instead they process each word in turn as it is read (or heard) off the input string. Furthermore, readers do not wait for the last word of the sentence in order to start the process of understanding the meaning of the sentence (Marslen-Wilson & Tyler 1980, with references therein). Sentences are parsed incrementally as words are associated with each other immediately as soon as they are detected, and partial interpretations are built. For example, when presented with the fragment {Mary gave …}, an English reader associates *Mary* as the subject of *gave* before the rest of the sentence becomes available.

In this paper, we report the preliminary results of two experiments investigating the processing of scrambling in Japanese, and discuss them in relation to two basic questions in sentence processing. First, how is the grammar used when sentences are processed? Second, is the word-by-word parsing process the same for all human languages, or are language-specific parameterizations necessary?

1.1 The grammar and incremental processing

Even complex grammatical constraints such as subjacency have an immediate

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effect in sentence processing in the sense that readers (we shall restrict the present discussion to reading) apply such constraints as early as possible rather than wait till the end of the sentence to filter out ungrammatical alternatives. For example, in the processing of fronted *wh*-phrases in English, readers create a gap for the *wh*-phrase as soon as grammatically permissible. This strategy can lead to mistakes as illustrated by the filled-gap effect (FGE) in the following sentence (adapted from Crain & Fodor 1985).

(1) [Who]$_i$ did the children force ^ us to sing the songs for 〈*gap*$_i$〉 yesterday?

As soon as the word *who* is read, it is clear that a corresponding gap has to be available in the input sentence, and readers attempt to insert such a gap at the earliest grammatical position available. (Throughout this paper, the antecedent of the gap will be marked with square brackets.) In (1), readers posit a gap at the position indicated with the wedge sign '^', so that the *wh*-phrase is initially interpreted as the direct object of force. When the next word *us* is read, it becomes apparent that the gap cannot be in this position and a FGE takes place as attested by slow reading times observed at this point compared to a control sentence (Crain & Fodor 1985, also Stowe 1986, for related results). Readers have to resume searching for the gap position, which is eventually found immediately after the preposition *for*. The FGE indicates that readers are not only attaching each incoming word immediately, but that they are also predicting how the sentence is going to continue by building portions of the mental representation (in the present case, by inserting the gap) without waiting for confirmation (i.e., without waiting to see if an overt direct object will follow).

A related finding is that no FGE is observed if the potential position for the gap is inside an island (Stowe 1986), suggesting that readers take island constraints into consideration in order to determine where to posit a gap.

In summary, the grammar actively determines the flow of the parsing process. Readers use grammatical knowledge not only to associate a word to the partial representation built thus far, but also in order to predict how the sentence fragment will continue.

1.2 Beyond the grammar: Parsing and parameterizations

Assuming that it is possible to separate the process of parsing sentences in two components—namely a grammar and a parser (i.e., an algorithm that uses a grammar to process sentences) —it is an open question whether the algorithm has to be parameterized for each language. Clearly, grammars are different for different languages in the sense that they vary in word order, they allow *wh*-phrases to be pronounced in different positions, and so forth. Similarly, it is conceivable that a different parser is used for each (type of) language; or alternatively, parameterizations may be restricted to the grammars, and a single parsing algorithm handles the processing of all natural languages.

In the following, we shall assume that a single parsing algorithm handles languages as different as English and Japanese (what we call the homogeneity of the parsing algorithm). There are a number of conceptual, methodological and empirical issues that lead us to adopt this assumption. For example, allowing variations in the parser would introduce inordinate complexities in language acquisition. Furthermore, it is methodologically unviable to show that the parser of two or more languages is exactly the same; therefore the homogeneity of the parsing algorithm is a reasonable assumption until compelling evidence to the contrary becomes available.

Under the homogeneity of the parsing algorithm, any potential differences observed in the processing of two languages have to be explained based on the interaction between the single parsing algorithm and the respective grammars of those languages. The goal of such a research project is to explain the processing of different constructions across various languages using the same processing mechanism.

We shall argue that the processing of scrambled constituents in Japanese takes place in a manner similar to the processing of fronted *wh*-phrases in languages such as English. The proposal has the advantage of using mechanisms that have been previously investigated in Dutch, English, Italian, and other similar languages; therefore their properties are well understood and they make clear predictions in the present case, as long as we consider some relevant differences between fronted *wh*-phrases and scrambled constituents.

2. The incremental processing of scrambling

We propose that Japanese readers insert the gap for a scrambled constituent as soon as grammatically possible. Consider how the word-by-word processing of the following fragment proceeds within our proposal.

(2) Ueitoresu-wa kokku-o
waitress-top cook-acc

Up to this point, a Japanese reader can assume that this is the beginning of a transitive construction in which a transitive verb (e.g., *saw*) will follow. However, when a dative NP is read next, it is clear that the NP sequence is more likely to be the beginning of a ditransitive clause in which the accusative NP precedes the dative NP. Assuming that the dative-accusative order is canonical (Hoji 1985), readers must posit a gap for the accusative NP, and the representation at this point would be as follows.

(3) Ueitoresu-wa [kokku-o]$_i$ rejigakari-ni 〈*gap*$_i$〉
waitress-top cook-acc cashier-dat

We assume that the verb need not be present in order for the gap to be posited, following an incremental processing model in which a partial representation of the sentence is created based on the case markers of the NPs (see Miyamoto 2002, and references therein).

Note that there is a crucial difference between the search for gaps in fronted *wh* constructions and in scrambling. In the former, as soon as a *wh*-phrase is detected, the reader knows that a gap is required. In scrambling, however, it is not always immediately clear that a constituent was scrambled. For example in (3), it is not clear that the accusative NP was scrambled until the dative NP is detected. Therefore, in *wh* processing there is the realization that a gap is necessary, and at a later point a gap is inserted. In scrambling, by contrast, the two processes occur simultaneously. The point at which it becomes apparent that a gap is necessary is often the position where a gap can be inserted. We shall not explore the possible consequences of such a difference in this paper, but this is the type of question that should be explored in the future.

According to previous processing results, the creation of a gap should have a number of behavioral effects. Below we provide the background for two such predictions, and then report the results of a self-paced reading experiment and a probe recognition experiment.

2.1 Measurable effects in the processing of gaps

Two types of effects have been observed in gap processing. The first observation is that the farther the gap is from its antecedent, the harder, and consequently the longer it takes for it to be processed (Gibson 1998, Just & Carpenter 1992).

Second, gaps have been shown to prime their antecedent; in other words, gaps facilitate the recollection of their antecedent (Bever & McElree 1988, MacDonald 1989). For example, consider the two English sentences below (from Bever & McElree 1988).

(4) a. Passive construction
[The *astute* lawyer who faced the female judge]$_i$ was suspected 〈*gap*$_i$〉 constantly.
b. Adjectival construction
The *astute* lawyer who faced the female judge was suspicious constantly.

After each sentence, a probe word was shown and native speakers of English had to answer whether the probe had appeared in the sentence. Reaction times to recognize *astute* after (4a) were faster than after its gap-less counterpart in (4b). The assumption is that the gap primes the entire NP headed by *lawyer*, therefore even portions of it (e.g., the adjective *astute*) are more quickly recognized.

If the processing of scrambling in Japanese involves the insertion of a gap, it should present effects similar to the ones just discussed. First, a gap should take longer to be processed if it is farther from the scrambled constituent. Second, a probe should be recognized faster if it is part of a scrambled constituent (cf. Nakayama 1995, who reports experimental results arguing against such a facilitation; but see Miyamoto & Takahashi 2002b, for a different interpretation of Nakayama's results). Note that the first prediction, which is tested in Experiment 1, implies longer reading times around the gap position, whereas the second prediction, tested in Experiment 2, involves faster recognition times of a probe presented after the sentence is read.

3. Experiment I—Self-paced reading

In this experiment, we measured reading times per region in various sentence types in order to show that longer latencies are observed if the gap is farther from its antecedent, namely the scrambled constituent. (See Miyamoto & Takahashi 2002a, for an overview of previous reading time results and a discussion of various factors that need to be considered in this type of experiment.)

3.1 Method

3.1.1 Participants

Thirty-two native speakers of Japanese, undergraduates at Kanda University of International Studies in the Kanto area of Japan, participated in the study.

3.1.2 Materials

Twenty sets with four sentences each were constructed. (See (5) for an example set.)

(5) a. Scrambled/Adjacent

Ueitoresu-wa	doogu-ga	okareteiru	sooko-de	[*kokku-o*]$_i$
waitress-top	tools-nom	stored	storage-loc	cook-acc
rejigakari-ni	〈*gap*$_i$〉	shookaishita	sooda.	
cashier-dat		introduced	seems	

b. Scrambled/Far
Ueitoresu-wa [*kokku-o*]$_i$ doogu-ga okareteiru sooko-de
waitress-top cook-acc tools-nom stored storage-loc
rejigakari-ni 〈*gap*$_i$〉 shookaishita sooda.
cashier-dat introduced seems

c. Canonical/Adjacent
Ueitoresu-wa doogu-ga okareteiru sooko-de *rejigakari-ni*
waitress-top tools-nom stored storage-loc cashier-dat
kokku-o shookaishita sooda.
cook-acc introduced seems

d. Canonical/Far
Ueitoresu-wa *rejigakari-ni* doogu-ga okareteiru sooko-de
waitress-top cashier-dat tools-nom stored storage-loc
kokku-o shookaishita sooda.
cook-acc introduced seems
'The waitress seems to have introduced the cook to the cashier in the storage room where the tools are stored.'

In the two Scrambled conditions (5a, b), the accusative NP *cook* was scrambled, whereas in the Canonical conditions (5c, d) it remains in its canonical position immediately before the verb. In the Adjacent conditions (5a, c), the two object NPs (*cashier*-dat and *cook*-acc) are adjacent to each other; in contrast, in the Far conditions (5b, d), an adjunct phrase (a locative or a temporal) intervenes between the two object NPs.

The region preceding the verb introduced is the crucial region for comparison. In both Scrambled conditions, a gap has to be posited for the scrambled accusative NP as soon as *cashier*-dat is read. However, because the distance between the gap being created and its antecedent is greater in the Scrambled/Far condition, we predict that participants will take longer to create the gap when reading *cashier*-dat in this condition in comparison to the Scrambled/Adjacent condition. In contrast, no such difference should be observed at the equivalent position, *cook*-acc, in the two Canonical conditions.

Four lists were created by distributing the test stimuli in a Latin Square design. Each participant saw exactly one of the lists intermixed with 50 unrelated foil items in pseudo-random order, so that at least one foil item intervened between two test items.

3.1.3 Procedure

The experiment was conducted on a Power Macintosh running PsyScope (Cohen, Mac-Whinney, Flatt, & Provost 1993) with a button-box. Participants were timed in a phrase-by-phrase, self-paced, non-cumulative, moving-window, reading task (Just, Carpenter, and Woolley 1982). Each phrase included a content word and a functional particle such as a case marker, a postposition, or a complementizer. The segmentation in the sentences in (5) (indicated with intervening spaces) was the actual segmentation used in the self-paced reading presentation. Sentences were shown using Japanese characters with the uniform-width font *Osaka Toohaba*. Stimuli initially appeared as dots with intervening spaces indicating the segments, and participants pressed the leftmost button of the button-box to reveal each subsequent region of the sentence and cause the present region to revert to dots. At the end of each sentence, a *yes/no* question appeared on a new screen; participants answered by pressing one of the two rightmost buttons of the button-box, and then auditory feedback was provided. Data points were eliminated from the reading time analyses if the participant did not answer the corresponding comprehension question correctly.

The experimental trials were preceded by one screen of instructions and eight practice trials. All sentences fitted on a single line and were presented without linebreaks. The experiment took participants approximately 15 minutes.

3.2 Results

3.2.1 Response accuracy

The average correct responses to the comprehension questions did not differ for the four conditions (Scrambled/Adjacent, 87.5%; Scrambled/Far, 88.7%; Canonical/Adjacent, 90.6%; and Canonical/Far, 91.9%; Fs < 1).

3.2.2 Reading times

The analyses of the reading time results for the critical region (the object NP preceding the main verb) were as follows. There was an interaction between position of the adjunct and word order ($F_1(1,31) = 7.95$, $P < 0.01$; $F_2(1,19) = 5.03$, $P < 0.05$). The Canonical/Far (787 ms) and the Canonical/Adjacent (842 ms) conditions did not differ ($F_1(1,31) = 1.54$, $P = 0.22$; $F_2(1,19) = 1.16$, $P = 0.29$); whereas the Scrambled/Far condition (903 ms) was slower than the Scrambled/Adjacent condition (763 ms; $F_1(1,31) = 5.84$, $P < 0.05$; $F_2(1,19) = 5.04$, $P < 0.05$).

There was an unexpected slow-down in the region preceding the critical region. The Canonical/Far condition (1055 ms) was slower than each of the other three conditions (Canonical/Adjacent 818 ms; Scrambled/Far 863 ms; Scrambled/Adjacent 847 ms; all Ps < 0.05); whereas the other three conditions did not differ from each other (all Fs < 1).

3.3 Discussion

As predicted, the Scrambled/Far condition was slower than the Scrambled/Adjacent condition in the critical region. This is the region that makes clear that the accusative NP *cook* was scrambled, and a gap is posited for this NP. Because of the intervening adjunct, the distance between the gap and its antecedent is greater in the Scrambled/Far condition, and consequently we observe longer reading times for this condition. The Canonical conditions, in contrast, do not differ, because there is no gap being posited at this point, and the position of the adjunct phrase is therefore irrelevant.

The long reading times at the adjunct head (*storage*-loc) in the Canonical/Far condition had not been predicted. There are two explanations that can be considered at this point, but we shall leave further investigation for future research. One possibility is that the slow-down at this point indicates that there is a gap being created for the dative NP *cashier*. In other words, the canonical position of the dative NP is after the adjunct. A second possible explanation is that readers were expecting an accusative NP to follow the dative NP (given that many verbs used in the experiment were ditransitives), and they were surprised when the adjunct head was detected instead.

4. Experiment II—Probe recognition

In this experiment, we measured the reaction time to recognize a probe word in order to verify whether there were any facilitation when the word is part of a scrambled constituent. (See Miyamoto & Takahashi 2002b, for further discussion and related results.)

4.1 Method

4.1.1 Participants

Thirty-five students and administrative staff from Kanda University of International Studies participated in the experiment. None of them had taken part in the previous experiment.

4.1.2 Materials

Twenty sets of items with two conditions each were constructed based on items used by Nakayama (1995).[1] See (6) for an example set. The two conditions have exactly

[1] We would like to thank Mineharu Nakayama for providing the original items of his experiment and for helpful discussion.

the same content words in the same linear order. The only difference is in the position of the accusative and nominative case markers in italics.

(6) a. Canonical condition
Gakkoo-de mondai-o dashita kooshi-*ga* mukuchina
school-loc question-acc asked lecturer-nom quiet
gakusei-*o* mita.
student-acc saw
'The lecturer who asked the question at school saw the quiet student.'
b. Scrambled condition
[Gakkoo-de mondai-o dashita kooshi-*o*]$_i$ mukuchina
school-loc question-acc asked lecturer-acc quiet
gakusei-*ga* 〈*gap*$_i$〉 mita.
student-nom saw
'The quiet student saw the lecturer who asked the question at school.'

The meaning of the sentences differs but there does not seem be an *a priori* advantage of one meaning over the other in relation to probe recognition. (In this respect, the present design is similar to that of Bever & McElree 1988, given that the agent and patient in their sentences in (4) are different as well.)

The second word in each condition (question in (6)) was used in the probe recognition task. Two lists were created by distributing the test stimuli in a Latin Square design. Each participant saw exactly one of the lists intermixed with 40 unrelated foil items in pseudo-random order.

4.1.3 Procedure

The self-paced reading setup was the same as the one used for Experiment 1. Moreover, immediately after the last region of the sentence was read, a probe word surrounded by underscores was presented on a new screen and participants had to decide whether it had appeared in the sentence by pressing one of the two rightmost buttons of the buttonbox. Next, participants answered a *yes/no* comprehension question appearing on a new screen. Auditory feedback was provided for the comprehension question only. Answers for the probe recognition task and for the comprehension question were counterbalanced for each list.

Data points for a sentence were included in the reading time analyses and in the probe recognition latency analyses only if the participant gave correct answers for the probe recognition and the comprehension tasks.

The experimental trials were preceded by one screen of instructions and eight practice trials. All sentences were presented on a single line. The experiment took participants approximately 15 minutes.

4.2 Results

4.2.1 Response accuracy and reading times

Probe recognition accuracy did not differ between the canonical condition (93.1%) and the scrambled condition (95.1%; Fs < 1.6). Response accuracy to the comprehension questions did not differ either (canonical, 78.2%; scrambled, 79.1; Fs < 1).

The reading time analyses per region revealed no reliable differences.

4.2.2 Probe recognition

Participants were faster to recognize the probe after reading sentences in the scrambled condition (888 ms) than in the canonical condition (931 ms; $F_1(1,34) = 4.72$, $P < 0.05$; $F_2(1,19) = 12.51$, $P < 0.01$).

4.3 Discussion

The faster reaction time to recognize the probe after the scrambled condition is compatible with the claim that the NP containing the probe was primed at the gap. Hence, the result supports the proposal that a gap is being created for the scrambled constituent. (See Miyamoto & Takahashi 2002b, for other related results and a discussion of Nakayama 1995, who did not detect reactivation in scrambled sentences; see also Nakano, Felser, and Clahsen 2002, for reäctivation in long-distance scrambling as measured with a cross-modal priming task.)

5. General discussion

At first sight it may seem hopeless to try to explain the processing of Japanese based on mechanisms proposed for English because of the structural differences between the two languages. Word order would seem a good case in point. Because word order is relatively rigid in English, it does not require the kind of processing mechanism that seems necessary to handle scrambling. Thus, one could have concluded that the parser of Japanese must be different from that of English. The present research suggests that this is in fact not the case. Even though ordinary word order in English does not provide a clue as to how scrambling is processed, there are nevertheless constituents (namely *wh*-phrases) that are pronounced far from their in-situ positions in this language. This commonality between fronted *wh*-phrases and scrambled constituents allows the proposal of a single processing mechanism in these cases.

The present paper has provided two types of evidence supporting the proposal that gaps are inserted during the processing of scrambled constituents. In particular, we have argued that the manner in which the gap is inserted is similar in scrambling and fronted *wh*-phrases. In both constructions, readers attempt to insert a gap for a prior constituent as early as grammatically permissible. This characterization of the parsing algorithm was only possible after we identified what the role of the grammar is in this process. The grammar determines the kinds of configurations that should generate the expectation for a gap as well as the possible positions where the gap may occur. The parsing mechanism chooses among those positions made available by the grammar and determines where the gap should be posited. Phenomena such as the filled-gap effect and the results of Experiment 1 indicate that the parser prefers to minimize the distance between gap and filler; therefore it inserts the gap at the earliest candidate position made available by the grammar.

The proposal allows us to explain the processing of scrambling based on a mechanism that has been characterized independently. Moreover, because the two constructions are not identical (e.g., *wh*-phrases trigger the search for a gap immediately, whereas in scrambling the search process is delayed), it should be possible to investigate more detailed aspects of the processing mechanism involved and how it is affected by idiosyncratic properties of the two constructions. Note that in this case the goal is not to look for differences between the two languages in order to propose a parameterization in the processing mechanism, but rather the intent is to look for differences between two types of constructions and investigate how they interact with the single processing mechanism assumed. In this sense, the fact that the constructions come from different languages is irrelevant for the most part, because we are not interested in characterizing the parser for a given language as opposed to another (type of) language. But rather, we want to determine the requirements that sentences with different types of configurations, regardless of whether they come from the same language or not, demand from the parser.

This immediately raises questions as to whether long-distance scrambling (i.e., cases in which a constituent is scrambled to a position outside its original clause) can be handled by the present proposal. In the sentences discussed in this paper, scrambling was VP-internal (in Experiment 1) or to the periphery of the clause (in Experiment 2). In principle, we assume that all types of scrambling should be processed in the same way, whether this is the case is an empirical question that is just beginning to be investigated. (See Aoshima, Phillips, and Weinberg 2002, Nakano, Felser, and Clahsen 2002, for relevant data.)

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日語攪拌規律處理裡的塡充語－空缺依存關係

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對於母語使用者的語法能力，心理語言學有兩個立即的問題須探討：第一、這樣的知識如何取得；第二、這個知識如何應用於處理輸入的語言訊號。本文探究第二個問題，採用逐字閱讀的心理實驗，結果支持日語攪拌句中含有空缺的分析。

關鍵詞：句子處理，日語，攪拌規律，剖析