1. Introduction

Sentence processing is one of the fastest growing fields and much is known about the mechanisms of English sentence processing. However, much of Japanese sentence processing mechanisms remain unknown. This paper attempts to explore the mechanisms of Japanese sentence processing, drawing examples from topic sentences in Japanese.

Japanese topic sentences violate Subjacency because topic phrases are not derived via movement but rather base generated and empty categories in topic sentences are pro (Saito 1985). Given this explanation, topic sentences in which topic phrases are coindexed with pros in relative clauses should be all grammatical; they are properly licensed by principles of the grammar within the framework of Government and Binding. However, some topics are acceptable, while some others are not, as illustrated by the following examples:

1a Hanako,-wa [ NP e1 e2 aishite-ita] hito,-ga jisatsu shite-shimat-ta]
    love-PAST  person2-NOM
   'Speaking of Hanako, the person who (s/he) loved committed suicide.'

1b Hanako,-wa [ NP e1 e2 aishite-ita] hito,-ga jisatsu shite-shimat-ta]
    love-PAST  person1-NOM
   Suicide do-PRFT-PAST
   'Speaking of Hanako, the person who loved him/her committed suicide.'

There remain questions about circumstances under which those topic sentences become unacceptable. To account for such contrast in acceptability of topic
sentences, various attempts were made in the past. For instance, Kuno (1973) proposes a pragmatic constraint called "aboutness relation", which must exist between a topic and the rest of the sentence. More strict grammatical conditions are also proposed. Hasegawa (1981) proposes a constraint appealing to grammatical relations between the topic and the head of a relative clause, on one hand, and their corresponding gaps. Ue (1982) claims Fodor's nested dependency constraint is applicable to Japanese topic sentences. Yet, none of these studies can successfully explain the acceptability and unacceptability of all the topic sentences that I will examine in this paper. The failure of the past analyses lies in the failure to consider parsing contexts, such that gaps are not all detected at once nor gaps are all filled at once in the parsing.

This paper examines a variety of topic sentences containing multiple gap dependencies, some of which have never investigated before, and shows that topic sentences become unacceptable due to some parsing difficulty; more specifically, it demonstrates that topic sentences result in parsing breakdown because the parser immediately and obligatorily constructs a syntactic representation of a word string and deterministically assigns a filler to a potential gap, which turn out illegitimate at the end of the sentence. This paper does not only explain how the acceptability/unacceptability of topic sentences with multiple gaps are determined but also suggests how the human parser comprehend topic sentences with multiple gaps in Japanese, which has not yet been studied in detail in the past.

Topic sentences containing multiple gaps create two major problems from a parsing perspective: gap detection and assignment of a filler to a potential gap. In what follows, we will show that topic

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1 When we investigate sentences from a parsing perspective, there is one more factor we have to consider, namely filler identification (cf. Clifftion and Frazier (1989)). In this paper I will not refer to this problem at all simply because the topic sentence does not create any interesting problems in identifying a filler. The filler in the topic sentence is clearly
sentences become unacceptable when the human parser fails to detect a gap and/or to assign a filler to an intended gap.

2. Gap detection

Japanese is a head-final language and hence complements of a head precede the head. When complements of a verb are phonetically null (empty categories), the existence of them in a sentence cannot be detected until a verb is encountered (until which point, nothing indicates the existence of gaps). Upon reaching a verb, the parser postulates gaps in accordance with the subcategorization information of that verb (see Inoue (1984) and Mazuka (1990) for similar views). For instance, in sentence 2 when the parser encounters the first verb, namely narat-ta, it realizes that two arguments of that verb are phonetically null and postulates two gaps as illustrated in 3:

2. sono-gakusee-wa kyonen narat-ta sensee-ga that student-TOP last year learn-PAST teacher-NOM naku-nat-ta die-PAST 'Speaking of the student, the teacher who he learned from last year died.'

3. sono-gakusee-wa [S e e kyonen narat-ta]

However, gaps are not always identified by the parser. When gaps are not successfully detected, the sentence is judged unacceptable. In the following two subsections, we will examine those unacceptable sentences and explore mechanisms employed by the parser to detect gaps.

2.2.1 Failure to detect a gap (I)

When there is a lexical NP that can be an argument of a verb, it is impossible to detect a gap for that position. For instance, in parsing example 4, there is a choice between taking the lexical NP, namely Taroo-ga as an argument of the first verb, aishite-i-ta and

marked with the particle wa and placed at the sentence initial position. Hence, I assume that the parser recognizes it without any special difficulties.
posing a gap for that position, as indicated 5.a and 5.b respectively:

4. Hanako-wa Taroo-ga aishite-i-ta hito-o
   TOP NOM love-PAST person-ACC
   koroshite-shimat-ta
   kill-PRF-PST
5.a Hanako-wa [ e [ S Taroo-ga e aishite-i-ta] hito-o] koroshite shimat-ta
   'Speaking of Hanako, she killed the person Taro loved.'

   b *Hanako-wa [ S Taroo-ga [ e e aishite-i-ta] hito-o] koroshite shimat-ta
   'Speaking of Hanako, Taro killed the person she loved.'

In 5.a the lexical NP, Taroo-ga is analyzed as the subject argument of the verb, aishite-i-ta and a gap is posited as the object argument of the verb. In 5.b two gaps are postulated as the arguments of the verb, aishite-i-ta, and the lexical NP, Taroo-ga is analyzed as the subject argument of the main verb, koroshite-shimat-ta.

Although these two interpretations of example 4 should be equally possible, (a)-interpretation is acceptable, while (b)-interpretation is not.

Similarly, the following example can be interpreted in two ways, yet only one interpretation is acceptable, as contrasted in acceptable example 7.a and unacceptatble example 7.b:

6. Hanako-wa Taroo-o aishite-ita hito-ga
   TOP ACC loved person-NOM
   koroshite-shimat-ta
   killed
7.a Hanako-wa [ S Taroo-o aishite-ita hito-o] koroshite shimat-ta
   'Speaking of Hanako, the person who loved Taro killed her.'

   b *Hanako-wa [ S Taroo-o aishite-ita hito-o] koroshite shimat-ta]
   'Speaking of Hanako, the person who she loved killed Taro.'

In 7.a, the lexical NP, namely Taroo-o is interpreted as the object argument of the verb, aishite-i-ta and a gap is posited as the subject argument of the verb. In 7.b, two gaps are posited as the arguments of the verb,
aishite-i-ta and the lexical NP, Taroo-o is interpreted as the object argument of the main verb, koroshite-shimat-ta.

The contrast in acceptability between the (a)-interpretation and the (b)-interpretation of each example above clearly demonstrates the intervening lexical NP prevents the parser from detecting a gap. Two pieces of evidence further support this claim.

First, when the intervening lexical NP in each example 5.b and 7.b, namely Taroo-ga and Taroo-o, respectively, is scrambled so that it does not precede the first encountering verb, the example with the intended interpretation results in acceptable, as shown in 8.b and 9.b:

8.a *Hanako,-wa [ S Taroo-ga [ S e1 e1 aishite-i-ta ] hito, ]1-o koroshite shimat-ta]1 (=8.b) 'Speaking of Hanako, Taroo killed the person she loved.'

     b Hanako,-wa [ S NP[ S e1 e1 aishite-i-ta ] hito]1-o,
                 Taroo-ga e1 k koroshite
                 shimat-ta]

9.a *Hanako,-wa [ S Taroo-o [ S e1 e1 aishite-ita ]
                 hito,j ]1-ga e1 koroshite-shimat-ta]1 (=7.b) 'Speaking of Hanako, the person who she loved killed Taroo.'

     b Hanako,-wa [ S NP[ S e1 e1 aishite-ita ] hito,j ]-ga
                 Taroo-o koroshite-shimat-ta]

Unlike 8.a, 8.b is acceptable because the object of the main verb, namely aishite-i-ta hito-o is fronted over the subject of the main verb, Taroo-ga, so that no lexical NPs that can be arguments of the first verb, aishite-i-ta precede the verb. Likewise, 9.b is acceptable because the object of the main verb follows the first verb and no lexical NPs that can be arguments of that verb precede it.

Second, when the Case particle of an intervening lexical NP indicates that it cannot be an argument of

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2In parsing English sentences, it is known that the parser sometimes prefers a lexical NP over a gap for some doubtful gaps (the "last-resort model of gap finding (Fodor 1978)). For a detail discussion of this principle, see Fodor.
a verb, gaps for that verb are all successfully identified. Observe the following examples:

10.a Hanako-wa Taroo-to aishite-i-ta hito-o
coroshite-shimat-ta
TOP with love-PAST person-ACC
kill-PRFT-PAST
'Speaking of Hanako, she killed the person who
she loved with Taroo.'

b Hanako-wa Taroo-ni aishite-i-ta hito-ga
tatte-shimat-ta
TOP with love-PAST person-NOM
meet-PRFT-PAST
'Speaking of Hanako, the person she loved met
with Taroo.'

c Hanako-wa Taroo-o dosookai-de at-ta
TOP school-reunion-at meet-PAST
hito-ga shitte-i-ta
person-NOM know-PAST
'Speaking of Hanako, the person she met at the
school reunion knew Taroo.'

In each of the above examples, the particle attached to the intervening lexical NP, namely Taroo indicates that this NP is not an argument of the first verb. For instance, in 10.b the first verb, aishite-i-ta takes only subject and object arguments. The NP immediately prior to the verb is marked with ni, which indicates that it is not the subject nor object. Hence, the parser successfully detects two gaps for the verb and the sentence results in acceptable, as in 10.b':


The above two pieces of evidence confirm that the parser cannot detect a gap when there is a lexical NP that can be an argument of a verb.

The preference for a lexical NP over a gap is not arbitrary but follows a very basic parsing principle. In the on-line processing of sentences with filler-gap dependencies, the processor's task is not limited to detecting gaps. Obviously, the processor identifies a gap while constructing a syntactic representation of an incoming word string. Although exact mechanisms of Japanese sentence processing remains to be more fully explored, I assume here that the Japanese parser make an initial structural representation on-line upon reaching an incoming constituent. Because Japanese is
a head-final language, complements of a head remain unattached until the head is reached. I will assume that when the head is reached, all the potential complements of a head is immediately and obligatorily attached to the head. Because of this parsing principle the parser fails to identify a gap when an NP that can be an argument of a verb precedes that verb. For instance, in parsing word string 11.a the second NP, Taroo-ga is attached as a complement of the verb, aishite-i-ta, as in 11.b, when that verb is reached, instead of being held unattached.

11.a Hanako-wa Taroo-ga aishite-i-ta hito-o
    TOP   NOM love-PAST  person-ACC
    koroshite-shimat-ta
    kill-PRFT-PST

b Hanako-wa [Taroo-ga e aishite-i-ta]

There are three pieces of evidence that supports this parsing principle.

The first evidence is based on a garden path sentence. The following example exhibits a strong garden path effect:

12. Taroo-wa imooto-ni Hanako-o shookai-shi-ta
    TOP sister-with   ACC introduce-PAST
    hito-ga koi-shite-i-ta
    person-NOM love-PAST
    'Speaking of Taroo, the person who he introduced Hanako to loved (his) sister.'

In parsing example 12, the parser initially analyzes the word string in the bold, Taroo-wa imooto-ni Hanako-o shookai-shi-ta, as a simple sentence, as in 13.a.

13.a Taroo-wa [ e imooto-ni Hanako-o shookai-shi-ta]

b *Taroo-wa [ e imooto-ni Hanako-o shookai-shi-ta]
    hito-ga koi-shite-i-ta

This analysis, however, breaks down when the main verb, koi-shite-i-ta is reached for the following two reasons. First, the topic NP, Taroo-wa is stranded without any corresponding gap. Second, the main verb, koi-shite-it does not have the dative argument and it is impossible to comprehend who the person that introduced Hanako to his sister loves. Hence, the parser must reanalyze the sentence and posit a dative
argument gap for the verb, *shookai-shi-ta*, as shown in 14.

      shookai-shi-ta] hito-ga e koi-shite-i-ta introduce-PAST person love-PAST
      'Speaking of Taroo, the person he introduced
      Hanako to loved (his) sister.'

The second evidence is based on a developmental study conducted by Clancy and her associates (1986). They report that Japanese children analyze the first word string, *zoo-ga kirin-o taoshi-ta* in example 15 as a simple sentence, which is ultimately proven to be incorrect.

15. Zoo-ga kirin-o taoshi-ta shika-o nade-ta
elephant-NOM giraffe-ACC knocked deer-ACC patted
   'The elephant patted the deer that knocked down the
giraffe.'

The third evidence is from an experimental study conducted by Mazuka and her associates (1989). They report the existence of *wild garden path* sentences in Japanese like example 16. In 16, the word string *roozin-ga kodomo-o yonda* is analyzed as a main sentence, which ultimately turns out incorrect.

16. Roonz-in-ga kodomo-o yonda jousee-to hanasi-o
    old man-NOM child-ACC called woman-with talk-ACC
    shita did
    'The old man talked to the woman who called the
    child.'

The above three pieces of evidence clearly demonstrate that the Japanese parser makes an initial syntactic representation of an incoming constituent. More specifically, the parser attaches all the potential NP arguments to a head immediately and

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3 Mazuka et al note that Japanese garden path sentences like 15 is not as sever as English garden path sentences fro unknown reasons.
obligatorily when the head is reached. This in turn proves that the parser fails to detect a gap when there is an NP that can be an argument of a verb.

2.2. Failure to detect a gap (II)

Because in the on-line processing, gaps are identified when a verb is reached, gaps of a higher verb in the syntactic structure cannot be detected until that verb is encountered later on. Observe the following example:

17. Tanaka kyoojuwa [NP wi np s e kai-ta]
   professor-TOP NNP write-PAST book-ACC
   honi-o koosee-shite-i-ta ga gakusee
   rectify-PROG-PAST student-NOM
   inakunatte-shimat-ta
   disappear-PRFT-PAST
   'Speaking of Prof. Tanaka, the student who was rectifying the paper that he wrote cannot be located.'

Notice in 17, the leftmost gap is not an argument of the verb the parser first encounters, but it is an argument of the next highest verb, koosee-shi-ta. Therefore, at the time the first verb, kai-ta is encountered the gap associated with the next highest verb cannot be identified in the left-to-right processing. This delay of the gap detection causes a serious problem in assigning a filler to a gap, which I will discuss in 3.

3. Assignment of a filler to a gap

In the previous section we have seen topic sentences result in unacceptable when an intended gap is not successfully detected. Even though gaps are successfully detected, some topics result in unacceptable because the parser fails to assign a filler to an intended gap. In this section, we will observe such topic sentences.

Some topic sentences become unacceptable when the parser fails to assign a filler to an intended gap. Observe the following oft-cited examples:

18.a Hanako-wa [NP wi np s e ai aishite-i-ta]
   TOP NNP love-PAST person-NOM
   shinde-shimat-ta
die-PRFT-PAST
'Speaking of Hanako, the person Hanako loved died.'

b *Hanako-wa [NP [S e_j e_i aishite-i-ta] hito-ga ʃTOP
shinde-shimat-ta
die-PRFT-PAST
'Speaking of Hanako, the person who loved Hanako died.'

Because of the examples like those cited above, it is assumed that Fodor's (1978) Nested Constraint is applicable to Japanese (for instance, in Ue (1982)). However, this constraint cannot explain acceptability/unacceptability of the following examples:

19.a Tanaka kyooju]-wa [NP [S e_i [NP [S e_j e_k kai-ta]
professor-TOP
hon] ]-o koosee-shite-i-ta] gakusee_j]-ga
book-ACC rectify-PROG-PAST studenti-NOM
inakunatte-shimat-ta
disappear-PRFT-PAST
'Speaking of Prof. Tanaka, the student who was rectifying the paper that he wrote cannot be located.'

b *Hanako-wa [NP [S e_i [NP [S e_j e_k kai-ta]
ʃTOP
ronbun]-o hihan-shi-ta] kyooju_j]-ga
paper-ACC criticize-PAST
hungai-shite-shimat-ta
professor-NOM resent-PRFT-PAST
'Speaking of Hanako, the professor resented her criticism of his paper.'

20.a Tanaka kyooju]-wa [NP [S e_i [NP [S e_j e_k kai-ta]

hon] ]-o koosee-shite-i-ta] gakusee_i]-ga

inakunattem-shimat-ta

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Hasegawa (1981) and Kornfilt et al (1981) also argue against the crossing constraint for reasons which differ from mine. I will not discuss their arguments here due to the limited space of this paper.
Notice that example 19.a is acceptable even though it exhibits crossing lines of filler-gap dependencies, as shown in 20.a. Hence, the crossing constraint incorrectly rules out 19.a. On the contrary, 19.b is unacceptable even though it does not exhibit crossing lines of filler-gap dependencies, as shown in 20.b. Hence, the crossing constraint does not rule out unacceptable example 19.b.

In order to explain the contrast in acceptability in the above examples, let us first examine differences between them in detail. 19.a contrasts sharply with 19.b in that the propositions associated with 19.a are all locally comprehended in the parse of that sentence, while the propositions associated with 19.b are not comprehended locally. There are three propositions associated with 19.a: i) Tanaka-kyooju-ga hon-o kaita "Prof. Tanaka wrote a book."; ii) gakusee-ga hon-o koousee-shi-ta "A student rectified the book."; and iii) gakusee-ga inakunat-ta "The student is missing." In the parse of 19.a these propositions are immediately comprehended without any delay when each verb and each head of the relative clauses are reached. That is, because the topic NP is assigned to one of the two gaps of the first verb and the first head of the relative clause is assigned to the other gap, the first proposition is comprehended at this point. The second proposition is understood when the second verb and the head of the second relative clause are encountered; the gap of the second verb is filled by the head of the second relative clause. Finally, the third proposition is comprehended when the third verb is encountered. Each of the three proposition in 19.a, hence is understood locally. On the contrary, in unacceptable 19.b three propositions are not locally comprehended. 19.b involves the following three propositions: i) kyooju-ga ronbun-o kai-ta "A professor wrote a paper."; ii) Hanako-ga ronbun-o hihan-shi-ta "Hanako criticized the paper." and iii) kyooju-ga hungai-shi-ta "The professor got angry (about it)." When the first verb is encountered two gaps associated with that verb are
detected. However, the topic NP is not assigned to one of these two gaps, but rather is held unassigned until the second verb is encountered. The first proposition cannot be comprehended until the head of the second relative clause is reached because the subject gap of the first verb is coindexed with that head. Hence, the first proposition fails to be comprehended locally. This seems to be the cause of unacceptability of 19.b.

In the parsing literature, it is assumed that the assignment of a filler to a gap is accomplished immediately when the gap is identified (Frazier 1985). Without much discussion, I also assume that in the parse of Japanese the filler is immediately assigned to a gap when it is detected. Under this assumption the parser successfully comprehend each proposition of a sentence locally if the filler is assigned correctly to the first detected gap, as we have seen in 19.a. In 19.b, however, the parser initially assigns the topic NP to the first detected gap and realizes this assignment is incorrect, resulting in the parsing breakdown. Hence, 19.b is unacceptable.

4. Conclusion

This paper discussed a long-noted problem, under what conditions topicalization from relative clauses result in unacceptable. I argue that the topicalization from relative clauses become unacceptable due to two types of parsing difficulties. One is that the parser fails to detect an intended gap due to the preference for a lexical NP over a gap and the other is that the parser fails to assign the topic NP to an intended gap due to the immediacy of the assignment of a filler to a gap.

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