Structural Computation and the Role of Morphological Markings in the Processing of Japanese

HIROKO YAMASHITA
University of Illinois at Urbana-Champaign

KEY WORDS
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ABSTRACT
In an SOV, strictly head-final language with otherwise relatively free word-order such as Japanese, disambiguating information including verb information is not available until the end of a clause. In such a language, a sentence theoretically has numerous possible syntactic structures before the verb information becomes available. The current study investigated (1) whether syntactic computation takes place in an ambiguous sentence fragment in Japanese and (2) if and how information from constituents other than the verb is utilized.

Two experiments were conducted using automated, word-by-word visual presentations with a lexical decision task on an extrasentential target. The results suggest that syntactic computation takes place in Japanese before verb information becomes available. A strong preference was observed for a simplex clause when three differently Case-marked arguments belonged to the same clause. The findings also indicate that information from surface Case marking is utilized productively, and when there is ambiguity, marking between arguments and adjuncts, the distinction is made before incorporating the constituents into the existing structure.

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Address for correspondence: Hiroko Yamashita, Dept. of East Asian Languages and Cultures, University of Illinois at Urbana-Champaign, 2090A Foreign Language Building, 707 South Mathews, Urbana, IL 61801 U.S.A. phone: +1 (217) 333–7036; fax: +1 (217) 244–4010; e-mail: <hyamash@uiuc.edu>.
INTRODUCTION

The study of ambiguities in sentence processing has received much attention. When and how the initial decision about syntactic structure is made is of particular interest (e.g., Ferreira & Henderson, 1990; Frazier & Clifton, 1996; Frazier & Fodor, 1978; Trueswell & Tanenhaus, 1994). The issue has been most often investigated in English, which is a head-initial, SVO language with highly limited and regulated occurrences of empty categories and a fairly strict word-order among arguments. Head-final SOV languages with null pronouns, such as Japanese, have not yet been fully investigated. A language like Japanese poses a challenge for Anglo-centric models because it allows numerous possible structures prior to the point when the disambiguating information becomes available to the parser (e.g., Inoue, 1991; Inoue & Fodor, 1995; Mazuka, 1991; Mazuka & Lust, 1990; Nakayama, in press). The current research asks whether syntactic computation takes place prior to the point at which the structural ambiguity is resolved in Japanese and examines sources of information productively used in the processing of Japanese.

The paper is organized as follows. First the difference between the types of ambiguities in English and Japanese is described. Then Experiment 1 investigates whether syntactic computation takes place before the verb. Upon confirming syntactic computation, Experiment 2 investigates how information from preverbal elements such as Case-marked arguments and adjuncts is utilized in Japanese; it asks whether or not the parser distinguishes an ambiguously ni-marked adjunct from a Dative Case-marked argument prior to the point at which verb information becomes available.

AMBIGUITIES IN ENGLISH AND JAPANESE

Ambiguity in English is usually triggered by the ambiguity of a function word as shown in (1), the omission of a complementizer as in (2), or the combination of both (e.g., Frazier & Clifton, 1996; Inoue, 1991). Typically, the number of ambiguities introduced by these variables is small in English. For instance, the ambiguous sentence fragments in italics in (1)–(3) may be completed in the following ways:

(1) morphological (lexical) ambiguity

That sick sheep should be kept in the barn…
   a. That sick sheep should be kept in the barn.
   b. That sick sheep should be kept in the barn is obvious.

(2) omission of a complementizer that

John knew the girl…
   a. John knew the girl.
   b. John knew the girl was from New York.

(3) morphological ambiguity + omission of overt relative pronoun

The horse raced past the barn…

1 A portion of the current study is based on the author’s dissertation, Yamashita (1994).
a. The horse raced past the barn.
b. The horse raced past the barn fell.

In contrast, the type of ambiguity in Japanese comes from a very different source: the combination of head-finality, scrambling, and phonologically null pronouns (e.g., Inoue, 1991; Mazuka, 1991; Mazuka & Lust, 1990; Nakayama, in press). First, due to the head-finality, the verb in Japanese is in clause-final position in both matrix and subordinate clauses, as shown in (4).

(4) a. John-ga Mary-ni hon-o ageta.

‘John gave Mary a book.’

b. John-ga Mary-ni Bill-ga hon-o yonda-to itta.

‘John said to Mary that Bill read a book.’

Sentence (4a) demonstrates the canonical order for simplex sentences in Japanese (Hoii, 1985). The verb follows three Nominative, Dative, and Accusative Case-marked NPs (arguments) marked by particles ga, ni, and o, respectively. Sentence (4b) contains a subordinate clause, Bill-ga hon-o yonda ‘Bill read a book’. In both matrix and subordinate
clauses, the verb is in final position. Consequently, there is a “stack” of arguments at the beginning of the sentence. Numerous studies demonstrate that stacked arguments in languages like Japanese add processing difficulty (Babylonyshev & Gibson, 1995; 1999; Lewis, 1996; Uehara, 1997).

Second, head-finitality makes Japanese a left-branching language, in which the most deeply embedded clause is located at the lower left of the syntactic tree. In (5), the relative clause modifying “the book” precedes the head noun, therefore making the syntactic structure branch out to the left.

(5) John-ga Tom-ga tosyokan-de karita hon-o yonda.

John-nom Tom-nom library-at borrowed book-acc read

‘John read the book that Tom borrowed at the library.’

Note that no relative pronouns or morphological markings signal the presence of a relative clause in modern Japanese. The relative clause is simply constructed by adding a head noun after a clause with the verb in plain form. Therefore, an ambiguity always exists between a simplex and a relative clause. Because the plain form is used predominantly in contrast to the polite (distal) form in both written and spoken language, such ambiguity is prevalent in Japanese.

Third, due to the phonologically empty pronouns, not all the arguments classified by the verb need to be overtly present as long as the referent is known or inferable. This is shown in (6b-d).

(6) a. Mary-ga hon-o yonda.

Mary-nom book-acc read

‘Mary read a book.’

b. Mary-ga yonda.

Mary-nom read

‘Mary read [it].’

c. Hon-o yonda.

book-acc read

‘[I/We/She/He/They] read a book.’
d. Yonda.
    read

'[I/We/She/He/They] read [it].'

Due to the null pronouns, sometimes the subject which signals the beginning of a clause is not always overtly expressed, as shown in (6c-d).

Finally, Japanese allows the permutation of arguments called “scrambling.” For instance, the arguments in (6a), Mary-ga and hon-o, may trade their places without major alternations to the semantics of the sentence.

These characteristics, namely, head-finality, phonologically null pronouns, scrambling, and nonexistence of relative pronoun, make unclear which portion of a sentence belongs to a matrix clause and which to a subordinate clause. Take, for instance, the beginning of a sentence as in (7). It may be a part of a simplex clause with a ditransitive verb as in (8). However, the sentence fragment in (7) may be a part of any of the structures in (9)–(10).

(7) Mary-ga John-ni ringo-o...
    Mary-nom John-dat apple-acc

(8) simplex clause completion
    Mary-ga John-ni ringo-o ageta.
    Mary-nom John-dat apple-acc gave
    ‘Mary gave an apple to John.’

(9) relative clause completion
       Mary-nom John-dat apple-acc ate person-acc introduced
       ‘Mary introduced the person who ate an apple to John.’
    b. Mary-ga John-ni ringo-o tabeta kodomotai-ni kubarasetta.
       Mary-nom John-dat apple-acc ate children-dat let distribute
       ‘Mary let John distribute the apple to the children who ate [it = lunch, etc.].’
    c. Mary-ga John-ni ringo-o ageta kodomo-o yobitometo omnahito-o mita.
       Mary-nom John-dat apple-acc gave child-acc stopped woman-acc saw
       ‘Mary saw the woman who stopped the child who gave an apple to John.’

(10) subordinate clause completion
       Mary-nom John-dat apple-acc Bill-nom ate-comp said
       ‘Mary said to John that Bill ate an apple.’
    b. Mary-ga John-ni ringo-o ageta-to itta.
       Mary-nom John-dat apple-acc gave-comp said
       ‘Mary said that [she] gave an apple to John.’
    c. Mary-ga John-ni ringo-o ageta-to itta.
       Mary-nom John-dat apple-acc gave-comp said
       ‘Mary said to John that [she] gave an apple to [him/her].’
The structures in (8)–(10) by no means exhaust all possible final structures of (7); there may be other, although less common, ways to complete the ambiguous string in (7). Furthermore, where null pronouns are possible, the ambiguity may sometimes not be resolved even at the end of a sentence without a clear context.

**Processing models**

Since a sentence fragment may be completed in so many different ways in a language like Japanese, it is natural to ask when the parser hypothesizes what the final syntactic structure would be, and how many hypotheses it makes. One possibility is that no syntactic computation takes place until enough information becomes available to the parser. Delay models of processing argue that the parser takes this approach. The strictest form of delay model is wholly “bottom-up,” hypothesizing that the parser does not build a dominating node until all the daughter nodes are identified. Mazuka and Lust (1988) propose that in general Japanese is best considered as bottom-up, although they claim that structure is serially computed within a clause. A modified and more relaxed version of the delay model, a partial delay model, posits a delay of limited duration. The “head-driven” parser proposed by Pritchett (1988, 1991) is based on this idea. In the head-driven model, it is hypothesized that no syntactic computation takes place until the verb appears in Japanese. Such models have an advantage in accounting for the processing of languages with massive ambiguities like Japanese because errors in processing are minimized regardless of the number of ambiguous structures.

Serial models (e.g., Frazier, 1978; Frazier & Clifton, 1996; Frazier & Fodor, 1978; Inoue & Fodor, 1995) argue that only the most syntactically simple structure is computed in an ambiguous string. Among the serial models, Inoue and Fodor (1995) propose a “ranked flagged serial” model to capture the difference between processing languages such as Japanese and English. Their model hypothesizes that a parser builds a structure on-line as a word appears, but leaves a signal, a flag, at potentially ambiguous places to indicate possible alternate structures as well as to record how highly each alternative is valued. Thus, when the parser is led down a garden path and needs to reanalyze the structure, it simply goes back to the flags and selects the most highly weighted flag, and then starts the reanalysis procedure. Inoue and Fodor claim that because the parser receives less information in Japanese than in English at each point of decision-making, a Japanese parser is “less confident” about each decision. With the phenomenon of scrambling and the existence of phonologically null pronouns, the parser in Japanese is always at risk of misanalysis. Moreover, the structure chosen as the first choice is not much better than the alternative structures. Lower confidence in decision-making, along with lower confidence in alternative structures, make the parser commit less to a structure in Japanese than in English. The result is that revisions are generally easier in Japanese than in English.

Another type of model is based on “parallelism”; that is, multiple structures are maintained in an ambiguous string. As enough information becomes available to the parser, structures proven different are dropped from consideration. The strictest type of parallel models assume that all possible structures are computed initially. A possible drawback of such models is the limitation of the human memory, which can handle only a limited number of structures at a time. Several “ranked-parallel” models have been proposed in order to resolve this problem. These models hypothesize “ranking” among multiple structures based
on syntactic complexity (e.g., Babyonyshev & Gibson, 1995; Gibson, 1991; Gorrell, 1987; 1989; Kurzman, 1985). Although the measure of complexity varies depending on the model, generally it is agreed that in English a simplex structure is simpler and therefore ranked higher than a structure with a subordinate clause such as a relative clause or a sentential complement. For instance, Gorrell (1987, 1989) experimentally demonstrated in English that multiple structures are computed and furthermore that they are ranked based on structural complexity.

Computational models developed by Gibson and his colleagues (e.g., Babyonyshev & Gibson, 1995; Gibson, 1991; Gibson & Thomas, 1995) also assume ranked parallelism. The factors determining the ranking in these models are two types of processing load (PLU): one associated with the number of arguments whose theta-role assigner has not appeared and the other associated with the number of self-embeddings (relative clause within a relative clause, sentential complement within a sentential complement). Sentences become unprocessable and are therefore dropped from consideration when the PLUs of a possible structure exceed a critical limit. If the interpretation turns out to be one of those which had been dropped from consideration, the parser experiences a garden-path effect, similar to that produced by serial models. The ranked parallel model is distinguished from the serial models because multiple structures are hypothesized and maintained as long as the PLU of each structure is low enough.

Just how Japanese is processed and which model best accounts for the language like Japanese must be experimentally investigated. Experiment 1 addresses the question of whether the parser postpones syntactic computation until the verb appears (or even later), or if it starts computing a structure before complete information becomes available. This experiment asks which structures are considered for a string of three differently Case-marked arguments, marked by Nominative, Dative, and Accusative markers.

**EXPERIMENT 1**

Experiment 1 uses the lexical decision task in Japanese. Gorrell (1987) utilizes the lexical decision to investigate syntactic processing with the understanding that a target is recognized as a real word faster if it fits in the syntactic structure computed when it appears (e.g., Goodman, McClelland, & Gibbs, 1981; Lukatela, Kostic, Feldman, & Turvey, 1983; Wright & Garrett, 1984). Thus, lexical decision appears to be a suitable task for determining which syntactic structures are computed at an ambiguous point, if at all. In the experiment, sentences like those illustrated in (11) were compared. Across the conditions, the sentence fragments are identical up to one word before the boldfaced word in (11a-d). Three Case-marked arguments appear in a canonical order. The boldfaced words are the lexical decision target words. In all conditions except the ungrammatical condition, the sentence fragments can be continued grammatically with the target words, but the syntactic structure that must be hypothesized in order to continue the sentence fragment grammatically varies according to the condition. The words following the target indicate a possible continuation if the target were to be integrated into an intended syntactic structure, but they were not actually shown in the experiment.
(11) a. simplex clause continuation

Gakkoo-de kawaii seito-ga sensee-ni oisii otya-o dasita kara.....
school-at cute student-nom teacher-to good tea-acc served because
‘Because at school, a cute student served good tea to the teacher…’

b. relative clause continuation

Gakkoo-de kawaii seito-ga sensee-ni oisii otya-o nonda hito-o
school-at cute student-nom teacher-to good tea-acc drank person-acc
syookai-sita.
introduced
‘At school, a cute student introduced to the teacher the person who drank the
good tea.’

c. ungrammatical continuation

*Gakkoo-de kawaii seito-ga sensee-ni oisii otya-o dakara
school-at cute student-nom teacher-to good tea-acc therefore
*‘At school, a cute student therefore good tea to the teacher…’

d. subordinate clause continuation

Gakkoo-de kawaii seito-ga sensee-ni oisii otya-o onnanohito-ga
school-at cute student-nom teacher-to good tea-acc woman-nom
nonda-to itta.
drank comp said
‘At school, a cute student told the teacher that the lady drank good tea.’

In the condition whose target words continues the sentence fragment as a simplex clause, the words for lexical decision are all ditransitive verbs in the past tense. In this condition, the sequence of three arguments may all belong to the same clause. Note, however, that even though a clause seems to be completed by the target word in the simplex clause condition, the target does not unambiguously mark the end of a clause; the clause may actually be a part of a sentential adjunct, as shown in (11a), or a part of a relative clause. In both cases, the sentence still continues after the target. All it signals to the parser is that the three arguments in the sentence fragment can be coarguments of the verb appearing as the target. In the relative clause continuation condition, the target words are transitive verbs which never take the Dative Case-marked argument, NP-ni, as their complements. The only way to continue the sentence fragment grammatically with the target is to assume a complex structure, such as the relative clause construction. In the ungrammatical condition, the target words for the lexical decision are conjunctions, which leaves no possible way to continue the preceding sentence fragment grammatically. The subordinate clause condition is another case of complex structure. In order to continue the sentence fragment grammatically, the parser must be aware that the Accusative Case-marked argument actually belongs to the subordinate clause and furthermore is scrambled within the subordinate clause. This condition is included because the transitive verb in the relative clause condition may be recognized as quickly as the ditransitive verbs in the simplex clause condition because the verb’s major syntactic categorical information fits the syntactic “slot.” If lexical
decision is blind to the subcategorization of a target verb and the parser attaches any verb according to minimal attachment, then the verbs in the relative clause condition should be recognized as quickly as those in the simplex clause condition, not as a result of parallel structures being computed, but by virtue of simply having the [+V] feature. Because the target words in the subordinate clause condition are [+N], rather than [+V], the subordinate clause condition would not be subject to the same artifact.

If no structure is computed in the ambiguous region, the lexical decision times and percentage of correct answers for the targets in the grammatical conditions, including simplex clause, relative clause, and subordinate clause conditions, should not differ from those in the ungrammatical condition.

Any structures initially computed should be reflected in shorter lexical decision reaction times and more correct answers than in the ungrammatical condition. Therefore, if only the simplex clause is computed, only the target words in the simplex clause condition should be recognized more quickly than those in the ungrammatical condition. Likewise, if all possible structures are computed, as predicted by the strictest parallel model, the recognition times should be lower and the percentage of correct answers should be higher in relative clause and subordinate clause conditions than in the ungrammatical condition.

If there is ranking among multiple structures, we would expect to see computation of structures although predictions would vary depending on the model. The prediction on the first three conditions by the ranked parallel model in Gibson (1991) is identical to serial models: it predicts that only the simplex clause is computed. In Gibson’s model, a structure that exceeds the simplest structure (the structure in the simplex structure condition in the current experiment) by two or more PLUs is dropped from consideration. In the simplex clause construction, the maximum PLU is reached in the simplex clause construction at the third argument, otya-o, where there are three arguments whose theta-roles are not assigned. If the parser assumes a relative clause construction, however, the structure will be dropped from consideration at this point because the PLU reaches 5 PLUs. The relative clause construction assumes three arguments within itself, a trace coinedexed with the head noun of the relative construction. Furthermore the relative clause itself is unassigned a theta-role. Since none of these has yet been assigned a theta-role, the total PLUs reaches five, more than the acceptable limit. The model predicts that the structure in the relative clause construction is dropped from consideration at the point of otya-o. No prediction is made regarding the subordinate clause condition by Gibson (1991) because the structure in the subordinate clause condition involves scrambling in the subordinate, to which the model does not refer.

**Method**

**Materials**

Four forms each of 24 sentence fragments were constructed as illustrated in (11). All test sentence fragments in Experiment 1 are given in Appendix A. Four lists were made by Latin square, each containing only one of the conditions per sentence fragment. Each list contained 24 different test sentence fragments, six per condition. These test sentence fragments in each list were combined with 72 fillers for a total of 96 sentence trials.
Prior to choosing 24 test sentence fragments, a sentence completion norm was established to minimize context effects in the lexical decision task, which is sensitive to pragmatic context as well as syntactic context (e.g., Fischler & Bloom, 1985; Schwanenflugel & Shoben, 1985). The sentence fragments used in the experiment must be neither inimical to the target nor so constraining that subjects can find very few words to continue the preceding sentence fragments.

In the completion norm, the first three arguments (NP-ga NP-ni NP-o) from the 24 target sentence fragments were embedded in 72 grammatical but incomplete sentence fragments. Ten native speakers of Japanese living in Columbus, Ohio, were asked to provide natural completions to all the test sentence fragments, using Japanese orthography. If a majority of subjects completed a given test sentence fragment using the same word, it was concluded that the context represented in the sentence fragment was pragmatically/semantically constraining, which made subjects expect certain words over others. Target sentence fragments that were completed with the same verb by more than 50% of subjects were replaced. In four sentence fragments out of 24, more than half of the subjects used the same verb for completion. Those four sentence fragments were changed to more neutral contexts, and were tested again by another 16 subjects as a follow-up to confirm that the context was not constraining. The average percentage of subjects completing the actual test sentence fragments in Experiment 1 using the same verb was 29.2%. This may seem high, but considering the preferred way of completion, it is not unreasonable. The completion pattern most frequently given by the subjects was a simplex clause followed by a ditransitive verb, the pattern used in the simplex clause condition in Experiment 1. Given that the number of ditransitive verbs able to plausibly continue the particular three arguments is limited to several verbs at most, such a percentage is not unreasonably high.

Among 96 sentence fragments in a list, 48 sentence fragments had real word targets and 48 had nonword targets. Of the 48 sentence fragments with real word targets, 24 were test items and 24 were fillers. Among the 24 fillers with real word targets, 12 had a target that grammatically continued the sentence fragments prior to the presentation of the target. Four of them had a target that started a new clause, and four had a target that completed the clause. The remaining four had targets that did not complete the sentence. Among the 48 sentence fragments with nonword targets, 16 had pseudoword targets that had legal morphological markings, 16 had phonetically possible combinations of Hiragana (Japanese syllabary) and Kanji (Chinese characters), and 16 had unusual combinations of Hiragana and Kanji. Katakana was not used in any targets due to its limited use. Each group of 16 sentence fragments with nonwords for targets had six sentence fragments that were completed right before the target presentation, and 10 that were not completed before the presentation of the target.

The number of characters in the target words was uniform across all conditions. Among 24 sets of test sentence fragments, 14 had target words of three characters and 10 had four characters. In the lexical decision experiment, about two-thirds of the nonwords were either pseudowords or complete nonwords that started off with Kanji and ended with Hiragana. One-third were wholly nonwords with Kanji and Hiragana mixed randomly; no nonwords were created using Katakana. In order to confirm that the response times for the lexical decision targets are due to the syntactic context and not due to frequency effects alone, a lexical decision task in isolation was carried out on all the target words. Twenty-
one native speakers of Japanese living in Kagawa, Japan were tested. The Analysis of Variance (hereafter ANOVA) revealed no significant difference in recognition times of the words across the conditions. No significant difference was observed in the percent correct either.

In order to keep the subjects paying close attention to the content of the sentence fragments, approximately a quarter of all sentence fragments were followed by a wh-question about the content of the previous sentence fragment. Identical questions were asked of all subjects. The questions could be answered with one word (such as ‘autumn’ or ‘the park’). These questions were asked in order to keep the subjects paying close attention to the content of the sentence fragments, as well as to distract them from noticing the recurring sentence pattern in the test conditions.

Subjects

Forty-six native speakers of Japanese living in Columbus, Ohio were paid to participate in the experiment. The ages of the subjects were between 18 and 54. All of the subjects had completed education up to (at least) high school in Japan. All had normal or corrected vision and all were naive to the purpose of the experiment. None of them had participated in the preliminary test or the written norm.

Procedure

The test was presented on a Macintosh SE30 with a button box, which recorded reaction time in milliseconds. Each time the subject pressed the “go” button, which is located on the right corner of the keyboard, a new test sentence fragment started. Each word of the sentence fragment appeared in the center of the screen for 300 ms and was immediately replaced by the next word. No subsequent words were presented.

The subjects were given no instructions as to the relationship between the syntactic context and the target word. They were instructed to read the sentence fragments and independently decide whether or not a lexical decision target was a real word in Japanese. They were to answer as quickly as possible after the target word appeared. If the target word was a real word, subjects pressed the button labeled ‘yes’, the rightmost of the five buttons. If the target was not a real word, subjects pressed the leftmost of the five buttons, which was labeled ‘no’. For the left-handed subjects the ‘yes’ and ‘no’ button positions were reversed. Subjects typed answers to the wh-questions on the Macintosh keyboard. They were allowed to type the answer either in Romanized Japanese or in English.

Before the test session, a practice session was carried out. The practice session contained 16 sentence fragments, including all the condition types for the test conditions. If a subject seemed to be having difficulty in the task after the first 16 practice sentence fragments, the identical practice session was repeated. Two people asked to repeat the practice session once, and were permitted to do so. None of the subjects wished to repeat the practice session more than twice. All subjects reported that they were confident after one or two practice session(s).

Results

Table 1 presents the mean reaction times and percentages correct for Experiment 1.


**TABLE 1**

Mean Response Times and Accuracy of Lexical Decision by Continuation Type

<table>
<thead>
<tr>
<th>Condition</th>
<th>Time(ms),(N)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplex clause</td>
<td>743 (263)</td>
<td>99.6</td>
</tr>
<tr>
<td>Relative clause</td>
<td>805 (258)</td>
<td>97.7</td>
</tr>
<tr>
<td>Ungrammatical clause</td>
<td>839 (242)</td>
<td>91.7</td>
</tr>
<tr>
<td>Subordinate clause</td>
<td>802 (255)</td>
<td>96.6</td>
</tr>
</tbody>
</table>

Before the statistical analysis, the following procedures were conducted. First, since the purpose of the current experiment was to observe syntactic effects on the lexical decision, data from two subjects who gave more than 10 wrong answers out of 26 *wh*-questions were eliminated because it was not clear whether these subjects were reading the sentence fragments accurately. Eliminating these subjects left 11 subjects for each list, and a total of 44 subjects.

Second, the response times for incorrect lexical decisions were excluded. The numbers in parentheses in Table 1 indicate the actual number of data points per cell. Following a commonly employed procedure to eliminate extreme outliers, the response times more than 2.5 *SD* away from the individual mean were replaced by the mean ± 2.5 *SD*. The significance level throughout the experiments in the current study was .05.

Both the response times and number of correct answers were subjected to one-way ANOVAs which included sentence continuation type as fixed factors and subjects or items as random factors. A one-way ANOVA indicated a significant difference in the response times across the sentence conditions, F1 (3,129) = 5.87, *p* < .001; F2 (3,69) = 5.00, *p* < .01. The post-hoc Tukey analysis by subjects revealed that the relative clause, ungrammatical, and subordinate clause conditions were significantly slower than the simplex clause condition at the .05 level. The post-hoc analysis by item revealed only that the ungrammatical condition was significantly slower than the simplex clause condition.

The number of correct answers across the four conditions was significantly different in analysis using ANOVA by subjects, F1 (3,129) = 9.13, *p* < .001, and by items, F2 (3,69) = 9.80, *p* < .001. The post-hoc Tukey analysis by subjects on the number of correct answers revealed only that the ungrammatical condition was correctly answered significantly less often than the simplex clause, relative clause, and subordinate clause conditions. There was no significant difference among the simplex clause, relative clause, and subordinate clause conditions at the .05 level.

**Discussion**

The main concern in this experiment was how simplex clause, relative clause, and subordinate clause conditions behaved in contrast to the ungrammatical condition. If there was no distinction among the four conditions, the results would indicate delayed computation of a structure. The response times showed that the two complex conditions and the ungrammatical condition patterned together, against the simplex clause condition. This result suggests that the three arguments marked by Nominative, Dative, and Accusative markers were placed in the same clause as soon as they appeared, and no complex structures were computed. In this sense, the results of response times are congruent with the
predictions made by both serial models and the ranked parallel model proposed in Gibson (1991), and not with delay models nor strict parallel models.

The number of correct answers on the lexical decision task, in contrast to the response times, appears to suggest computation of not only the simplex structure but also other complex structures. Relative clause and subordinate clause conditions behaved like the simplex clause condition, as would be predicted if multiple structures were computed. However, the results of the correct responses must be suffering from ceiling effect, as shown in small standard deviation for each condition (simplex clause = .06, relative clause = .14, ungrammatical = .28, subordinate clause = .18).

**Information from Word-order and Case Marking**

The results of Experiment 1 clearly show that a parser initiates syntactic processing before substantial information about the sentence is provided by the verb; within three Case-marked arguments, processing seems to begin. This finding leads one to ask just what type of information other than the verb is utilized by the parser in the initial processing. Information provided by argument, such as information from Case markers, semantic contents of arguments, and word-order, are prime candidates (e.g., Inoue, 1991; Lewis, 1996; Mazuka & Lust, 1988). Various models claim that Case information is utilized in the processing of Japanese, as it has also been shown in English and German (e.g., Meng & Bader (2000); Scheepers, Hemforth, and Konieczny, 1998; Traxler and Pickering, 1996). However, exactly how it is used in Japanese has not been made clear. Recall that in Experiment 1, all test sentence fragments had three differently Case-marked arguments in the canonical order, *ga-ni-o*. Was Case information critical to the initial parsing decisions, or was it the order in which Case-marked arguments appeared?

A partial answer is given in Yamashita (1997), which reports effects of the number of identically Case-marked arguments and no effects of ordering. Using a self-paced, word-by-word reading task, Yamashita (1997) compared reading times of sentences identical except in word-order, as shown in (12). The reading times were higher for the underlined third argument in (12a) than for the underlined arguments in the other conditions.

(12) a. canonical order in both matrix and subordinate clause

\[
\text{Denwa-de hansamuna gakusee-ga sensee-ni tsumetai koibito-ga} \\
\text{phone-on handsome student-nom teacher-dat cold girlfriend-nom} \\
\text{nagai tegami-o yabutta-to itta.} \\
\text{long letter-acc tore-comp said}
\]

b. subordinate object scrambled

\[
\text{Denwa-de hansamuna gakusee-ga sensee-ni nagai tegami-o tsumetai} \\
\text{phone-on handsome student-nom teacher-dat long letter-acc cold} \\
\text{koibito-ga yabutta-to itta.} \\
\text{girlfriend-nom tore-comp said}
\]
c. matrix indirect object and subordinate object scrambled

Denwa-de sensee-ni hansamuna gakusee-ga nagai tegami-o tsumetai
phone-on teacher-dat handsome student-nom long letter-acc cold
koibito-ga yabutta-to itta.
girlfriend-nom tore-comp said

‘On the phone, a handsome student told the teacher that the cold-hearted girlfriend had torn the long letter.’

Sentence (12a) follows canonical order for a sentence with a sentential complement, while the other two conditions are scrambled. While two Nominative Case-marked arguments appear within the first three arguments (the first and third arguments) in (12a), the other conditions have all differently Case-marked arguments. Despite the fact that words were canonically presented, the reading times of condition (12a) at the third argument koibito-ga, ‘girlfriend’, were higher than the Accusative Case-marked arguments at the same position in (12b) and (12c). The results demonstrate that processing the second Nominative Case-marked argument before the verb required extra cost compared to processing a set of differently Case-marked arguments which could all potentially belong to the same clause. The findings suggest that the parser preferred to interpret the first few arguments as coarguments of a simplex clause. More importantly, the study demonstrates that the parser keeps track of the number and types of Case-marked arguments regardless of the order in which they appear, and Case information is utilized immediately.

**Ambiguity in the Surface Marking**

The finding in Yamashita (1997) and the results of Experiment 1 in the current study suggest that the Case marking plays a role in processing prior to the point at which the verb information becomes available. The combined results lead us to the next question on the role of markers. Notice that while Case markers appear to be a strong source of information, there are not completely unambiguous in their function. The marking by a particle in Japanese does not always correspond to grammatical functions (subject, object) or categorical information such as NP or VP of the word to which it is attached, due to the ambiguity on the morphological level. For instance, the Nominative Case marker ga does not always mark the subject of a sentence; it also marks the object of predicates such as stative predicates and verbs with a potential morpheme (e.g., Kuno, 1973). The particle ni is also ambiguous. The marker ni marks various arguments of grammatical functions including the argument receiving the goal theta-role and an underlying agent of a passive or causative structure, among others (Sadakane, 1992; Sadakane & Koizumi, 1995). What is of most serious concern is that the Case marker ni is identical to the morpheme of commonly used adjuncts such as manner and temporal adjuncts, as shown in (13).

(13) a. **John-ga san-zi-ni coora-o nonda.**
John-nom three-o’clock-at cola-acc drank
‘John drank some cola at 3 o’clock.’

b. **Mary-ga kantan-ni mondai-o toita.**
Mary-nom easily question-acc solved
‘Mary solved the question easily.’
The adjunct phrases *san-zi-ni* ‘at three o’clock’ and *kantan-ni* ‘easily’, superficially have the same composition as the Dative Case-marked argument; they both are composed of an NP followed by the particle *ni*. In order to recognize the constituent *san-zi-ni* as an adjunct, the meaning of the NP *san-zi* ‘three o’clock’ or *kantan* ‘ease’, must be understood. However, the constituents do not serve as an adjunct unless they are marked appropriately by *ni*. Without the adverbial marker *ni*, the sentence does not make sense.

Compare the surface markings in (13) with the simplex clause condition used in Experiment 1, repeated below as (14).

(14)  
\begin{quote}
Gakko-de kawaii seito-ga sensee-ni oissi oya-o dasita kara...
\end{quote}

school-at cute student-nom teacher-to good tea-ace served because

‘Because at school, a cute student served good tea to the teacher...’

Notice that the markers in (13) and (14) are identical: *ga, ni*, and *o*. During initial processing, does the parser distinguish the types of *ni*-marked constituents in (13) and (14)? If the parser does not distinguish them and simply “skims” the information from the particles, (13) and (14) would be considered identical by the parser. In other words, the parser could not determine that (14) has three arguments, while (13) has only two arguments and one constituent, *san-zi-ni* or *kantan-ni*, which is an adjunct.

By contrasting simplex clause and relative clause conditions in Experiment 1, we know that the *ni*-marked argument is not recognized automatically as an adjunct phrase. If it had been, the reaction times in the simplex clause condition should have followed the same pattern as the relative clause condition. This was clearly not so, indicating that at least the combination of an NP and the particle *ni* in Experiment 1 was recognized as an argument. Then, are the adjuncts marked by *ni* shown in (13) initially incorrectly identified as argument and incorporated in a hypothesized structure?

Whether the parser simply scans information from particles or distinguishes an adjunct from an argument has profound theoretical consequences. It affects almost all argument-based models whose processing decisions are based on the argumenthood of a constituent, or the models whose processing load is based on the number of arguments. For instance, Clifton, Speer, and Abney (1991) propose a model in which the initial syntactic decision is determined by the major categories (for instance, PP, NP) and the preference for adjunct attachment emerges only on the second pass. For instance, both argument and adjunct PPs in sentences such as “The man expressed his interest *in a wallet/*in a hurry* during the storewide sale at Steigers” were initially attached as the direct daughter of VP. The preference for such minimal attachment is accounted for by the category of those phrases; they are both PPs which consist of a preposition and a NP. Then the structure with adjunct, *in a hurry*, undergoes reanalysis later as the parser processes the post-PP portion of the sentence.

Note that Japanese poses a problem comparable to English PP attachment. Even though temporal adverbs such as *san-zi-ni* are adjuncts, the composition of *san-zi-ni* is analogous to a Dative Case-marked argument: an NP followed by a particle *ni*. If the parser regards *san-zi-ni* as a Case-marked argument, then the model of Clifton et al. predicts that the phrase will be attached as an argument of a simplex clause. Later the structure will undergo reanalysis. Alternatively, if evidence shows that the adjunct is attached initially in a different way from a Dative Case-marked argument, then, to account for the processing
of Japanese, the model of Clifton et al. must incorporate a mechanism that distinguishes arguments from adjuncts prior to attachment, despite analogous surface marking.

The recognition of the argument/adjunct distinction is also relevant to some of the serial models. In the Construal hypothesis proposed in Frazier and Clifton (1996), the type of attachment to the existing structure is determined by the argumenthood of a phrase. Frazier and Clifton claim that immediate attachment to an existing phrase is restricted to the “primary” phrases such as a main predicate and their arguments. Note that a PP is ambiguous in English because it is potentially a primary phrase (an argument), but it also may be an adjunct. Frazier and Clifton (1996) propose that such an ambiguous string of PPs is attached as a primary phrase by default, and later reanalyzed if necessary. If the parser utilizes the information from marking alone in processing Japanese, then an adjunct such as san-zi-ni in (13a) is attached as a primary phrase, despite the fact that it is an adjunct. If the parser quickly recognizes san-zi-ni as an adjunct and attaches it as a “nonprimary” constituent, then at least in Japanese, default primary phrase attachment of argument-adjunct ambiguities is not a valid strategy.

Predictions made by ranked-parallel models such as those proposed in Gibson (1991) and Babayonyshev and Gibson (1995, 1999) would change if argument/adjunct distinction is not made immediately. In these models, processing cost is incrementally added each time the parser encounters an argument. If san-zi-ni is to be initially processed as an argument, the initial calculation of processing load in Gibson’s models must be made not by the number of arguments but purely by particle surface marking. For these reasons, we now examine whether the parser can distinguish arguments from adjuncts even when there is ambiguity in surface marking.

**EXPERIMENT 2**

Experiment 2 investigated how the information from the surface marking by a particle interacts with the status of the constituent, that is, the argument and adjunct distinction. The lexical decision task was used on sentences like those illustrated in (15).

(15) a. dative-ditransitive continuation

*Mukutina syokuin-ga sibui otya-o kakarityoo-ni dasita kara.....
quiet secretary-nom bitter tea-acc section chief-dat served because
‘Because a quiet secretary served bitter tea to the section chief…”

b. dative-transitive continuation

*Mukutina syokuin-ga sibui otya-o kakarityoo-ni nonda ato
quiet secretary-nom bitter tea-acc section chief-dat drank after
*dasita kara.....
served because
‘Because a quiet secretary served bitter tea to the section chief after she drank it…”

c. adjunct-transitive continuation

*Mukutina syokuin-ga sibui otya-o san-zi-ni/sizuka-ni nonda kara.....
quiet secretary-nom bitter tea-acc 3 o’clock-at/quietly drank because
‘Because a quiet secretary drank bitter tea at 3 o’clock/quietly…”
The boldfaced words in each condition are the lexical decision target words, which serve to disambiguate the structure. Across the conditions, the sentence fragments up to two words before the boldfaced word, _otya-o_, in (15a-c) were identical. Then one word before the target varied. While in the dative-ditransitive and dative-transitive conditions, the word was the Dative Case-marked argument, in the adjunct-transitive condition, the word was a temporal or manner adjunct.

Despite the difference in the word immediately before the target, the surface marking across the conditions was identical: three constituents were marked by _ga_, _o_, and _ni_, respectively. The target word in the dative-ditransitive condition grammatically continues the preceding sentence fragment and completes it as a simplex structure. On the other hand, a grammatical continuation of dative-transitive fragments demands a complex structure because the transitive verb target does not take three arguments. According to the results of Experiment 1, such response times would be slower than the dative-ditransitive condition.

What is critical is the adjunct-transitive condition, which has two arguments, each marked by _ga_ and _o_, and a temporal or manner adjunct in the sentence fragment. The target word is a transitive verb. All adjuncts selected in the stimuli are commonly used, unambiguous manner or temporal adjuncts.

Note that the word-order in this experiment was changed from _ga-ni-o_, the one used in the previous experiment, to _ga-o-ni_. The order was changed in order to present the target words immediately after the critical word, _ni_-marked constituents, in all conditions. If we used the _ga-ni-o_ order as in Experiment 1, the critical words (_ni_-marked words) would appear two words before the disambiguating target words, and we would only be able to measure the “spillover effects” of the ambiguous marking of _ni_. The word-order change should not affect the prediction. According to Yamashita (1997), transitive verb targets after three arguments in noncanonical order were recognized as slowly as those after three canonically ordered arguments.

If the parser is blind to the content of the _ni_-marked word and simply utilizes information from surface markings, then the parser would not differentiate between dative-transitive and adjunct-transitive conditions. The parser would treat both conditions as if there are three arguments which will be placed in a simplex clause, as coarguments of the ditransitive verb. Therefore the transitive verb in both conditions should not be considered compatible with the structure computed up to that point. Consequently the recognition times of both dative-transitive and adjunct-transitive conditions would be longer than those for the dative-ditransitive condition. Alternatively, if the parser is sensitive to the content of the _ni_-marked word and detects that the _ni_-marked word in the adjunct-transitive condition is an adjunct, then it should correctly treat the preceding sentence fragment as two arguments and one adjunct. In this case, the transitive verb in the adjunct-transitive condition will grammatically continue the simplex structure that had been computed up to this point. The recognition times of the adjunct-transitive condition would be, in this case, no longer than those in the dative-ditransitive condition, and shorter than those in the dative-transitive condition.
Method

Materials
Twenty-four different base sentence fragments were constructed. For each, three forms were devised corresponding to (15a-c), and these were assigned to three lists by Latin square. A complete list of test sentence fragments are given in Appendix B. Test sentence fragments in each list were combined with 80 fillers for a total of 104 trials. Approximately 1/4 of both test and filler sentences were followed by questions asking the content of the immediately preceding sentence fragment. To streamline the procedure, all were yes/no questions. As in Experiment 1, prior to the experiment the target words were pretested in a lexical decision test in isolation by 21 naive subjects, Japanese native speakers living in Kagawa, Japan. A one-way ANOVA revealed no significant difference in recognition times of the words across the conditions.

Subjects
Forty-two native speakers of Japanese living in Urbana-Champaign, Illinois were paid to participate in the experiment. All of the subjects had completed education up to (at least) high school in Japan and lived in America less than 10 years. They all had normal or corrected vision and they were all unaware of the purpose of the experiment. None of them had participated in the preliminary tests.

Procedure
The test materials were presented on a Power Macintosh 7100/60 screen. The sentence fragments were all presented automatically, word-by-word, in a moving-window fashion. Subjects pressed the return key of the keyboard to start each trial. As soon as the subject pressed the button, an asterisk appeared at the left-center of the screen with a beep sound. After 400 ms, the asterisk disappeared and the first word replaced it. Stimulus duration increased to 350 ms from the 300 ms used in Experiment 1, because subject feedback indicated that 300 ms/word was uncomfortably fast. Each word appeared and stayed on the screen for the duration of 350 ms. Fifty ms after the last word of the sentence or sentence fragment disappeared, the lexical decision target word was presented at the lower right corner of the screen, independent of where the fragment appeared.

If the target word was a real word, subjects pressed the return key on the keyboard. If the target was not a real word, subjects pressed the tab key. For answering the yes/no questions, which followed about 1/4 of the trials, subjects used the y/n keys on the keyboard. Each test session was preceded by a practice session in which subjects saw 15 sentence fragments; the practice sessions included all of the condition types from the test conditions.

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2 Four subjects in Experiment 1 complained that the presentation (300 ms) was sometimes too fast to comprehend the sentence fragments. In contrast, none commented that the rate of presentation was too fast in Experiment 2, in which the rate was changed to 350 ms.
TABLE 2
Mean Response Times and Accuracy of Lexical Decision by Continuation Type

<table>
<thead>
<tr>
<th>Condition</th>
<th>Time (ms), (N)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dative-ditransitive</td>
<td>677 (310)</td>
<td>99.4</td>
</tr>
<tr>
<td>Dative-transitive</td>
<td>777 (307)</td>
<td>98.7</td>
</tr>
<tr>
<td>Adjunct-transitive</td>
<td>704 (306)</td>
<td>99.0</td>
</tr>
</tbody>
</table>

Results

Table 2 presents the mean reaction times and percentages correct for Experiment 2.

Before the statistical analysis, the data was treated in a manner identical to Experiment 1 except the following. Data from three subjects were rejected because of mechanical error. No subjects were eliminated for poor comprehension, as all scored at least 24 out of 30 yes/no questions. Therefore the data from all 39 subjects, 13 per list, were analyzed.

Both the response times and number of correct answers were analyzed by one-way ANOVAs which included sentence continuation type as fixed factors and subjects or items as random factors. The analysis by an ANOVA revealed a significant difference in the response times, $F(1, 276)$ = 8.83, $p < .01$; $F(2, 46)$ = 5.23, $p < .01$, across the conditions. The post-hoc Tukey subject analysis on the response times revealed that the response times for the dative-transitive condition were significantly longer than those in the dative-ditransitive and adjunct-transitive conditions at the .05 level. There was no significant difference between response times in the dative-ditransitive and adjunct-transitive conditions. There was no significant difference in the accuracy of lexical decision answers across the conditions ($F(2, 276) < 1$).

Discussion

The results show that transitive verbs were recognized significantly more slowly only when the transitive verb target was preceded by three Case-marked arguments. The response times for the dative-transitive condition were longer than the dative-ditransitive and adjunct-transitive conditions, which did not differ significantly. The overall results are congruent with the hypothesis that the parser distinguishes adjuncts from arguments by the time the disambiguating target words appear, despite ambiguous morphological marking.

Even though the lexical decision task in Experiment 2 measures only one point in processing, we can eliminate the possibility that *ni*-marked adjuncts were initially attached as an argument in a matrix clause. If adjuncts in the adjunct-transitive condition had actually been attached as arguments, the transitive verb targets in the adjunct-transitive condition should have patterned with the dative-transitive condition. This was clearly not so.

The results of Experiment 2 have theoretical implications for various proposed models. In the serial model, under the Construal hypothesis, temporal and manner adjuncts are not attached as arguments to the syntactic structure computed up to that point in the initial analysis in Japanese. Rather, adjuncts receive different consideration from arguments...
prior to the attachments. In the ranked-parallel models proposed in Gibson (1991) and Babaynyshev and Gibson (1995), \textit{ni}-marked temporal and manner adjuncts should not add extra PLUs and therefore would not incorrectly influence their predictions of Japanese.

\section*{GENERAL DISCUSSION}

The current study examined the nature of initial processing of Japanese, prior to the point where verb information becomes available. The study highlighted two remarkable characteristics of the Japanese parser. One is that the Japanese parser is highly opportunistic, as argued in Inoue and Fodor (1995). The study demonstrated that in Japanese before the verb information becomes available to the parser syntactic processing takes place using Case information, as many studies have suggested (Inoue, 1991; Lewis, 1996; Mazuka & Lust, 1988). When three differently Case-marked arguments, \textit{ga}, \textit{ni}, and \textit{o}, appeared consecutively, as in Experiments 1 and 2, a simplex clause was constructed. On the other hand, when Case-markers strongly signaled the possibility of alternate structures, for example the identical markers signaling the possible subordinate clause in (12) (from Yamashita, 1997), the processing cost increased immediately. These phenomena suggest that the Japanese parser immediately takes advantage of Case information, that is, the type and number of Case-marked arguments.

Recent studies further support the initiation of processing in Japanese without verb information. The Event-Related Potential study in Garnessy, Yamashita, Ito, and McClure (1999) asked subjects to read the sentences analogous to the subordinate clause condition in Experiment 1 of the current study. They observed that when the second Nominative-marked argument indicated the existence of a complex structure, the subjects demonstrated P600, reflecting their detection of syntactic anomaly. Garmsey et al. (1999) conclude that Japanese subjects garden-pathed at the second Nominative-marked argument, when the expectation of a simplex clause completion was proven incorrect. In a self-paced reading experiment, Kamide and Mitchell (1999) also report a preference to consider the first few arguments as the coarguments of a matrix clause before the sentence-final disambiguation.

Experiment 2 further highlights the opportunistic aspect of the parser. The results showed that on-line the parser not only utilized the Case marking but also other morphological marking information. An adjunct marked by an identical \textit{ni}-marker was not blindly attached as an argument but is attached as an adjunct from the beginning. In other words, the Japanese parser initiates syntactic processing by aggressively utilizing information on arguments and adjuncts which appear prior to the verb.

The study found, at the same time, that the Japanese parser is highly optimistic. Both experiments showed strong evidence that the parser hypothesizes the simplex clause. This preference is in accord with Minimal Attachment (Frazier & Fodor, 1978) or Local Association (Frazier & Fodor, 1978), and lists Japanese among other languages such as Korean (Yamashita, 1994) or German (Meng & Bader, 2000), and English that observe such principles. At the same time, the study has shown that the parser is quite unprepared for cases in which the initial simplex clause hypothesis is proven incorrect; neither experiment detected the computation of structures other than the simplex clause. Recall that we have observed earlier that a number of structures are theoretically possible for only
few arguments in Japanese. Considering the fact that more than half of Japanese sentences are syntactically complex, that is, include either a relative clause or a subordinate clause (Yamashita, 1994), the lack of parallelism in processing Japanese might strike one as quite counterproductive.

Recently, the debate over parallel versus serial processing has once again attracted much attention (e.g., Gibson, 1991; McRae, Spivey-Knowlton & Tanenhaus, 1998; Richardson & Spivey, 1999; Spivey, Fitneva, & Tabor, 1999). A comparison of the current study and the experimental evidence for parallelism in English possibly explains why parallelism was not detected in the current Japanese experiments and when the human parser may compute parallel structures in general. Recall that the options for how an ambiguous string may unfold in English are narrowed down significantly at the verb because of the fairly strict order constraints for arguments and the early availability of verb information. In the NP/S ambiguity shown in (2), the number of ambiguous structures is limited to the number of possible argument structures. In the main verb/reduced relative ambiguity in (3), only two structures exist that may continue the ambiguous string grammatically. Most experimental evidence for parallelism known in English attests to the existence of the unpreferred (nonminimal attachment) structure in a binary choice such as the sentential complement structure in NP/S ambiguity as shown in (2b), or the reduced relative clause structure in the main verb/reduced relative ambiguity as in (3b).

In contrast to English, hardly any grammatical information in Japanese narrows down the number of ambiguous structures prior to the end of a sentence. Verbs indeed provide effective information, such as the nature of the event and its participants, via their argument structure; but usually they do not narrow down the number of possible structures to a binary choice. For instance, the transitive verb which follows three arguments as shown below eliminates the possibility of a simplex structure because it does not take the Dative-marked argument as an argument and Nominative-marked argument does not scramble. Therefore the transitive verb signals the parser that the Nominative-marked and Dative-marked arguments belong to the matrix clause. However, because the beginning of a relative clause is not marked and because phonologically null pronouns may be present in the string, whether the Accusative-marked argument belongs to the matrix clause or relative clause is still not known at the verb.

(16) Seito-ga *sensee-ni otya-o nonda... student-nom teacher-to tea-acc drank

Likewise, a ditransitive verb which follows arguments marked by ga, ni, and o, signals that the clause may be completed as a simplex clause. But with a phonologically null pronoun and an unmarked beginning of a relative clause, such a sentence fragment may begin a globally ambiguous sentence containing a relative clause as shown below.

(17) Seito-ga *sensee-ni otya-o dasita hito-o syookai-sita. student-nom teacher-dat tea-acc served person-acc introduced

‘The student introduced to the teacher the person who served [someone] some tea.’

‘The student introduced [to someone] the person who served some tea to the teacher.’

Not only verbs but also the number of arguments sometimes offer some structural information. More than three stacked arguments, as in the subordinate condition in
Experiment 1, also eliminate the possibility of a simplex clause. Once again, however, the final structure is not revealed by the number of arguments alone because the clause boundary between the matrix and subordinate clause is not marked in Japanese. As noted in Inoue (1991) and Inoue and Fodor (1995), information which leads the parser to confident decisions is scanty in Japanese.

With differences in the quality of information each language gives to the parser, we question how plausible it is to assume that parallelism is a universal strategy. Note that recent studies reveal that the quality of disambiguating information affects the efficiency of reanalysis (Bader, Meng, & Bayer, 1999; Fodor & Inoue, 1994; 1999; 2000; Meng & Bader, 2000). For instance, Meng and Bader (2000) show that disambiguating information that signals simply the presence of a misanalysis requires more reanalysis cost than information that leads the parser to single correct structure for reanalysis. If quality of information affects reanalysis, then, one can imagine that it may affect initial processing. In particular, it is quite possible that parallel structures are computed only when the number of alternatives can be significantly narrowed down by effective disambiguating information. When the evidence leaves just two possible structures, as in the case of ambiguities in English, temporal parallelism in structural computation may promote efficient processing. On the other hand, because of the many possibilities and sparse effective information in Japanese, computing multiple structures which may or may not be realized as ambiguities in Japanese is less practical than pursuing the simplest structure and reanalyzing as it becomes necessary. In this sense, the seemingly infinite possible structures of Japanese may not be visible to the parser, and consequently parallelism may be less of an issue. Similar experiments in Korean, a language with extremely similar grammatical characteristics to Japanese, also show no evidence of parallel computation (Yamashita, 1994). This pattern further casts doubts on parallel processing in languages with scarce definitive information.

Of course, this discussion of parallelism in languages like Japanese is limited to the structures examined in the current study, and more different structures must be examined in the future. It is of particular importance to discover whether the Japanese parser indeed computes unpreferred structures in the environment similar to English ambiguous sentences, that is, when definitive information significantly narrows down the number of alternative structures. If unpreferred structures are computed in Japanese only when definitive information significantly narrows down the possible structures, then both English and Japanese parsers may adjust their degree of parallelism to the quality of the processing information. If no computation of an unpreferred structure is detected in Japanese even when alternative structures are narrowed down, then a language-specific processing strategy may be at work.

It is certainly tempting to simply interpret the evidence of parallelism in languages like English as a universal phenomenon. However, the results of current study, in conjunction with the lack of possible benefits in computing multiple structures in Japanese, cast serious doubts on the computation of all possible unpreferred structures. For this reason investigation of parallelism in all types of languages is imperative. An examination of languages like Japanese or Korean is critical because their grammatical characteristics relevant to processing differ greatly from those of English.

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REFERENCES


APPENDIX A

Stimuli for Experiment 1

The italicized words are targets for lexical decision. Target words are in the order of simplex clause, relative clause, ungrammatical, and subordinate clause conditions.

(1) Ofisu-de zimi-na syokuin-ga kakarityoo-ni sibui otya-o office-at plain office worker-nom section chief-dat bitter tea-acc dasita/nonda/dakara/zyosee-ga served/drank/therefore/woman-nom

(2) Tookyoo-de iyarasii hoomonkyaku-ga seezika-ni mezurasii kabin-o Tokyo-at unpleasant visitor-nom politician-dat rare vase-acc miseta/kazatta/sikazi/zyotyuu-ga showed/displayed/but/woman-nom

(3) Kyositsu-de yasasii sensee-ga daigakusee-ni hukuzatu-na koosiki-o classroom-at gentle teacher-nom college student-dat complicated formula-acc situmon-sita/hakken-sita/dakedomo/yoomuin-ga questioned/discovered/however/janitor-nom


(5) Matikado-de kiza-na syoonen-ga zyosidaisee-ni omoi nimotu-o street corner-at stuck-up boy-nom female college student-dat heavy luggage-acc watasi/suteta/masaka/ekiin-ga handed/throw away/by no means/train station worker-nom

(6) Syokudoo-de takumassii takusi-no unentsyu-ga obasan-ni yasui teesyoku-o restaurant-at stout taxi-gen driver-nom middle-aged lady-dat cheap set meal-acc tyuumon-sita/aziwatta/keredomo/wakamonotati-ga ordered/tasted/however/young people-nom

(7) Inaka-de keti-na sakka-ga musuko-ni ii kamera-o countryside-at stingy writer-nom son-dat good camera-acc yuzutta/kowasita/sikaruni/syasinka-ga gave/broke/however/photographer-nom

(8) Kyooto-de ganko-na syuzin-ga desi-niatarasii kikai-o Kyoto-at stubborn master-nom clerk-dat new machinery-acc makaseto/ugokasita/naruhodo/yuumeenin-ga left (to him)/operated/indeed/celebrity-nom

(9) Zitaku-de omosiroi onisan-ga yuuzin-ni hen-na bideo-o home-at interesting brother-nom friend-dat strange video-acc kasita/uttasita/dakedo/nakama-ga lent/shot/but/friend-nom

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(10) Sitamati-de siraga-no obaasan-ga komeya-ni hurui syakklin-o
downtown-at gray-haired old lady-nom rice merchant-dat old debt-acc
haratta/wasureta/tadasi/sakaya-ga
paid/forgot/however/liquor merchant-nom

(11) Sutazio-de umai kasyu-ga otoosan-ni mizikai uta-o
studio-at good singer-nom father-dat short song-acc
sasageta/kiita/sorede/okyaku-ga
dedicated/listened/then/customer-nom

(12) Oosaka-de heta-na zyouyu-ga kantoku-ni kuroi tebukuro-o
Osaka-at bad actress-nom director-dat black gloves-acc
nageta/nuida/datte/kankyaku-ga
threw/took off/but/audience-nom

(13) Eki-de zyouhin-na huzin-ga tyoonan-ni taisetu-na kaban-o
station-at sophisticated lady-nom first son-dat important bag-acc
azuketa/kakaeta/tokorode/tomodati-ga
deposited/held/by the way/friend-nom

(14) Kaigi-de wakai katyou-ga syain-ni zansin-na sinseehin-o
meeting-at young section chief-nom office workers-dat fresh new product-acc
hiroo-sita/hihan-sita/tinami-ni/tyuugakusee-ga
demonstrated/criticized/incidentally/junior high school student-nom

(15) Nooka-de henkutzna roozin-ga hitorimusume-ni hiroi toti-o
farmhouse-at obstinate old man-nom only daughter-dat large land-acc
nokosita/tukatta/keredo/himago-ga
left/used/hoverer/great grandchild-nom

(16) Depaato-de umai tenin-ga onnanoko-ni hade-na yooohuku-o
department store-at good clerk-nom girl-dat flashy clothes-acc
susumeta/sityaku-sita/tokoroga/kookoosee-ga
recommended/tried on/but/high school student-nom

(17) Bazaa-de kappatu-naka okusan-ga minna-ni oisii okasi-o
charity-at active wife-nom everyone-dat good cake-acc
yaita/tabeta/desuga/kodomo-ga
baked/ate/but/child-nom

(18) Hirosima-de yooki-na seenen-ga kootyoo-ni takai piano-o
Hiroshim-at cheerful younger-nom principal-dat expensive piano-acc
todoketa/naosita/tumari/sityoo-ga
delivered/reppaired/in other words/mayor-nom

(19) Baa-de mazusii ongakuka-ga odoriko-ni utukusii hanataba-o
bar-at poor musician-nom dancer-dat pretty flower-acc
ageta/motta/nanoni/tizin-ga
gave/held/ despite/acquaintance-nom
(20) Nagasaki-de akarui syoozyo-ga oneesan-ni mezurasii omiyage-o
Nagasaki-at bright girl-nom sister-dat rare souvenir-acc
*tanonda/yorokonda/saredo/kyuuyuu-ga*
asked/was pleased at/however/classmate-nom

(21) Resutoran-de tanomosii dansec-ga koibito-ni gooka-na yubiwa-o
restaurant-at dependable man-nom girlfriend-dat gorgeous ring-acc
*okutta/kantee-sita/sunawati/uriko-ga*
sent/appraised/in other words/sales clerk-nom

(22) Kooen-de tisai otokonoko-ga ryoozin-ni ooki-na kyandee-o
park-at small boy-nom parents-dat big candy-acc
*nedatta/sisyokusita/sikaraba/nakayosi-ga*
asked/tried/then/good friend-nom

(23) Kenkyuusitu-de yarite-no senpai-ga kyoozyu-ni akai tubo-o
lab-at capable senior man-nom professor-dat red vase-acc
*tukatta/watta/naraba/koohai-ga*
made/broke/in that case/junior man-nom

(24) Yokohama-de utukusii zyoyuu-ga haahoya-niikkooii kuruma-o
Yokohama-at pretty actress-nom mother-dat good-looking car-acc
*katta/tometa/yueni/otona-ga*
bought/parked/therefore/adults-nom

**APPENDIX B**

**Stimuli for Experiment 2**

First, second, and third sentences in each set represent dative-ditransitive, dative-transitive, and adjunct-transitive conditions, respectively. The italicized words are the targets for lexical decision. Sentences 1–12 contain the temporal adjunct, and 13–24 contain the manner adjunct.

(1) Mukuti-na syoukin-ga sibui otya-o kakarityoo-ni dasita
quiet office worker-nom bitter tea-acc section chief-dat served
Mukuti-na syoukin-ga sibui otya-o kakarityoo-ni nonda
quiet office worker-nom bitter tea-acc section chief-dat drank
Mukuti-na syoukin-ga sibui otya-o sanzi-ni nonda
quiet office worker-nom bitter tea-acc 3 o’clock-at drank

(2) Yasasii syuhu-ga kireena kabin-o syujin-ni miseta
gentle housewife-nom pretty vase-acc husband-dat showed
Yasasii syuhu-ga kireena kabin-o syujin-ni kazatta
gentle housewife-nom pretty vase-acc husband-dat displayed
Yasasii syuhu-ga kireena kabin-o syoogatu-ni kazatta
gentle housewife-nom pretty vase-acc New Year’s Day-on displayed
(3) Kowai sensee-ga hukuzatuna koosiki-o gakusee-ni questioned
strict teacher-nom complicated formula-acc student-dat
Kowai sensee-ga hukuzatuna koosiki-o gakusee-ni hakkensita
strict teacher-nom complicated formula-acc student-dat discovered
Kowai sensee-ga hukuzatuna koosiki-o saisyo-ni hakkensita
strict teacher-nom complicated formula-acc first-at discovered

(4) Wagamamana kodomo-ga ookina kyandee-o hahaoya-ni nedatta
spoiled child-nom big candy-acc mother-dat requested
Wagamamana kodomo-ga ookina kyandee-o hahaoya-ni sisyokusita
spoiled child-nom big candy-acc mother-dat tried
Wagamamana kodomo-ga ookina kyandee-o yuugata-ni sisyokusita
spoiled child-nom big candy-acc evening-in tried

(5) Isogasii kangohu-ga nagai kusuri-o kanzya-ni nokosita
busy nurse-nom bitter medicine-acc patient-dat left
Isogasii kangohu-ga nagai kusuri-o kanzya-ni suteta
busy nurse-nom bitter medicine-acc patient-dat threw away
Isogasii kangohu-ga nagai kusuri-o getumatu-ni suteta
busy nurse-nom bitter medicine-acc end of the month-at threw away

(6) Mazimena syoonen-ga atui ziten-o gakusee-ni watasita
serious boy-nom thick dictionary-acc student-dat handed
Mazimena syoonen-ga atui ziten-o gakusee-ni tukatta
serious boy-nom thick dictionary-acc student-dat used
Mazimena syoonen-ga atui ziten-o yonaka-ni tukatta
serious boy-nom thick dictionary-acc night-at used

(7) Takumasiu untensyu-ga yasui teesyoku-o obasan-ni tyuumonsita
masculine driver-nom cheap special (meal)-acc middle-aged lady-dat ordered
Takumasiu untensyu-ga yasui teesyoku-o obasan-ni aziwatta
masculine driver-nom cheap special (meal)-acc middle-aged lady-dat tasted
Takumasiu untensyu-ga yasui teesyoku-o hazime-ni aziwatta
masculine driver-nom cheap special (meal)-acc first-at tasted

(8) Ketina sakka-ga ii kamera-o zyosyu-ni yuzutta
stingy writer-nom good camera-acc assistant-dat gave
Ketina sakka-ga ii kamera-o zyosyu-ni kowasita
stingy writer-nom good camera-acc assistant-dat broke
Ketina sakka-ga ii kamera-o syoogatu-ni kowasita
stingy writer-nom good camera-acc New Year’s Day-on broke

(9) Omosiroy kodomo-ga henna bideo-o otona-ni kasita
funny child-nom strange video-acc adult-dat rented
Omosiroy kodomo-ga henna bideo-o otona-ni utusita
funny child-nom strange video-acc adult-dat filmed
Omosiroy kodomo-ga henna bideo-o yonaka-ni utusita
funny child-nom strange video-acc night-at filmed
(10) Umai tenin-ga aoi yoohuku-o onnanoko-ni susumeta
    good salesperson-nom blue clothes-acc girl-dat recommended
Umai tenin-ga aoi yoohuku-o onnanoko-ni sityakusita
    good salesperson-nom blue clothes-acc girl-dat tried on
Umai tenin-ga aoi yoohuku-o getuyooobi-ni sityakusita
    good salesperson-nom blue clothes-acc Monday-on tried on

(11) Kappatuna okusan-ga oisii okasi-o nakama-ni yaita
    active housewife-nom delicious cake-acc friends-dat bakcd
Kappatuna okusan-ga oisii okasi-o nakama-ni tabeta
    active housewife-nom delicious cake-acc friends-dat ate
Kappatuna okusan-ga oisii okasi-o gogo-ni tabeta
    active housewife-nom delicious cake-acc afternoon-in ate

(12) Mazusii ongakuka-ga tiisana hanataba-o odoriko-ni ageta
    poor musician-nom small bouquet-acc dancer-dat gave
Mazusii ongakuka-ga tiisana hanataba-o odoriko-ni motta
    poor musician-nom small bouquet-acc dancer-dat held
Mazusii ongakuka-ga tiisana hanataba-o saigo-ni motta
    poor musician-nom small bouquet-acc last-at held

(13)Namaikina huryoo-ga sosokkasii kookoossee-o syoozyo-ni syookaisita
    mischievous punk-nom clumsy high school student-acc girl-dat introduced
Namaikina huryoo-ga sosokkasii kookoossee-o syoozyo-ni kudoita
    mischievous punk-nom clumsy high school student-acc girl-dat persuaded
Namaikina huryoo-ga sosokkasii kookoossee-o gooin-ni kudoita
    mischievous punk-nom clumsy high school student-acc forcefully persuaded

(14) Gankona syuzin-ga taisetuna kikai-o desi-ni makaseta
    stubborn master-nom important machine-acc disciple-dat let operate
Gankona syuzin-ga taisetuna kikai-o desi-ni ugosakisa
    stubborn master-nom important machine-acc disciple-dat operated
Gankona syuzin-ga taisetuna kikai-o muri-ni ugosakisa
    stubborn master-nom important machine-acc forcefully operated

(15) Sekoi oziisan-ga hurui syakkin-o komeya-ni haratta
    stingy grandpa-nom old loan-acc rice vendor-dat paid
Sekoi oziisan-ga hurui syakkin-o komeya-ni wasureta
    stingy grandpa-nom old loan-acc rice vendor-dat forgot
Sekoi oziisan-ga hurui syakkin-o tanzyun-ni wasureta
    stingy grandpa-nom old loan-acc simply forgot

(16) Umai kasyu-ga mizikai barado-o huan-ni sasageta
    good singer-nom short ballad-acc fan-dat dedicated
Umai kasyu-ga mizikai barado-o huan-ni kiita
    good singer-nom short ballad-acc fan-dat listened
Umai kasyu-ga mizikai barado-o nessin-ni kiita
    good singer-nom short ballad-acc enthusiastically listened
(17) Zyoozuna zyoyuu-ga atui tebukuro-o kantoku-ni nageta
    good actress-nom thick gloves-acc director-dat threw
Zyoozuna zyoyuu-ga atui tebukuro-o kantoku-ni nuida
    good actress-nom thick gloves-acc director-dat took off
Zyoozuna zyoyuu-ga atui tebukuro-o kantan-ni nuida
    good actress-nom thick gloves-acc easily took off
(18) Zyoohinna huzin-ga kooka-na kaban-o ekiinn-ni azuketa
    sophisticated lady-nom expensive purse-acc conductor-dat left
Zyoohinna huzin-ga kooka-na kaban-o ekiinn-ni kakaeta
    sophisticated lady-nom expensive purse-acc conductor-dat held
Zyoohinna huzin-ga kooka-na kaban-o sintyoo-ni kakaeta
    sophisticated lady-nom expensive purse-acc carefully held
(19) Wakai katyoo-ga zansinna sinseehin-o syain-ni hiroosita
    young chief-nom fresh new product-acc colleague-dat showed
Wakai katyoo-ga zansinna sinseehin-o syain-ni hihansa
    young chief-nom fresh new product-acc colleague-dat criticized
Wakai katyoo-ga zansinna sinseehin-o seesiki-ni hihansa
    young chief-nom fresh new product-acc officially criticized
(20) Rittina seenen-ga takai piano-o kootyoo-ni todoketa
    rich man-nom expensive piano-acc principal-dat delivered
Rittina seenen-ga takai piano-o kootyoo-ni naosita
    rich man-nom expensive piano-acc principal-dat fixed
Rittina seenen-ga takai piano-o sinsetu-ni naosita
    rich man-nom expensive piano-acc kindly fixed
(21) Akarui syoozyoo-ga mezurasii omiyage-o sakka-ni tanonda
    bright girl-nom rare souvenir-acc write-dat asked
Akarui syoozyoo-ga mezurasii omiyage-o sakka-ni yorokonda
    bright girl-nom rare souvenir-acc write-dat appreciated
Akarui syoozyoo-ga mezurasii omiyage-o sunao-ni yorokonda
    bright girl-nom rare souvenir-acc honestly appreciated
(22) Henkutuna roozin-ga gookana yubiwa-o koibito-ni okutta
    stubborn old man-nom gorgeous ring-acc girlfriend-dat sent
Henkutuna roozin-ga gookana yubiwa-o koibito-ni kanteesita
    stubborn old man-nom gorgeous ring-acc girlfriend-dat appraised
Henkutuna roozin-ga gookana yubiwa-o seekaku-ni kanteesita
    stubborn old man-nom gorgeous ring-acc accurately appraised
(23) Yarite-no zyosyu-ga sugoi sakuhin-o syuzin-ni tukutta
    good assistant-nom awesome work-acc master-dat made
Yarite-no zyosyu-ga sugoi sakuhin-o syuzin-ni wara
    good assistant-nom awesome work-acc master-dat broke
Yarite-no zyosyu-ga sugoi sakuhin-o ukatu-ni wara
    good assistant-nom awesome work-acc carelessly broke
(24) Sekkatina syatyoo-ga akai kuruma-o hisyo-ni katta
impatient president-nom red car-acc secretary-dat bought
Sekkatina syatyoo-ga akai kuruma-o hisyo-ni tometa
impatient president-nom red car-acc secretary-dat stopped
Sekkatina syatyoo-ga akai kuruma-o muri-ni tometa
impatient president-nom red car-acc forcefully stopped