On-line Processing of
Syntactically Ambiguous Sentences
by Japanese University Students

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Abstract: This paper describes two experiments which examine how Japanese university students process syntactically ambiguous sentences in English. In Experiment 1, four sentences including prepositional phrases (PP) were presented visually word by word along with VP-biasing, NP-biasing, and Neutral contexts. The results showed that the preference toward VP attachment is not always observed, and the context affects the processing slightly. The results also showed that no significant difference is observed between English majors and non-English majors. In Experiment 2, sentences containing (1) NP, and NP’s NP3, (2) VP + NP + Relative-Clause + Adv., (3) Adj. + NP1 and NP2 constructions were presented in the same way as in Experiment 1 along with three kinds of context. The results showed that the extent to which context affects the processing of sentence parsing differs in each kind of sentence.

Introduction

Whether syntactic or semantic factors work more efficiently in natural language processing has been discussed frequently (e.g., Carrithers, 1989; Vosniadou, 1982). To this question, Frazier & Fodor (1978) propose the Syntax-First Model, that is, that syntactic factors contribute greatly to language processing. In contrast, Tyler & Maslen-Wilson (1979) propose the Content-Guided Processing, that is, although the correspondence exists between the form and meaning, little syntax is required in language processing. Besides these two factors, a third, contextual information, has also been discussed. However, the results of the research do not show uniformity: Schustack et al. (1978) and Warner & Grass (1978) recognize the effect of context in language processing whereas Britt et al. (1992) and Rayner (1992) suggest little effect of
context. This discrepancy may stem from the idiosyncrasy of the materials used, that is, whether they are garden-path sentences (e.g., When the boys strike the dog kills), sentences including prepositional phrases (e.g., The boy hit the girl with the boomerang), or sentence including reduced relatives (e.g., The woman rushed to the hospital had given birth safely).

The present study investigates the processing of sentences including prepositional phrases. The above sentence is ambiguous in that the prepositional phrase 'with the boomerang' can be attached either to the verb phrase (VP) or to the noun phrase (NP) 'the girl'. The primary concern of the present study is to see whether the effect of context on processing differs between the two ways of attachment. To this end, VP-biasing and NP biasing contexts are prepared. The present study is also concerned with whether processing differs between native and non-native speakers of English. To this end, Japanese students learning English are employed, since most of the research mentioned earlier has used subjects speaking English as a native language. The present study also investigates the processing of sentences including other ambiguous constructions. To this end, two kinds of coordinate phrases and one relative clause + Adverb construction are prepared.

**Experiment 1**

**Subjects**

The subjects were Japanese university students learning English as a foreign language. In order to see the difference in the proficiency of English, ten English majors (mean age 21) and twelve non-English majors (mean age 22) were employed. None of them were reported to have speech or visual disorders.

**Stimulus Sentences**

Four target sentences including prepositional phrases were prepared. The main criterion in preparing these sentences was that they could be interpreted twofold depending on the way of attachment. The second criterion was that they were uniform in their syntactic construction (Subject Noun + Verb + Object Noun + Prepositional Phrase) and length (eight words). The third criterion was that the words used show high familiarity for Japanese students.

Three kinds of two-sentence contexts were prepared—VP-biasing, and NP-biasing, and Neutral. The VP-biasing context was made to induce the VP-attachment interpretation whereas the NP-biasing context was made to induce the NP-attachment interpretation. The neutral context was made to induce both interpretations equally. In preparing the context, care was taken to make the syntactic construction as uniform as possible across the three kinds of context.

The final test material consists of a total of 12 sets of Context + Target. Besides, questions for confirming the comprehension and forced-choice answers were prepared. These are shown
in Appendix A.

Procedure
The presentation of the materials was conducted under the control of a personal computer (NEC PC-9801 NS/R). Following the instruction 'Push any key when ready', five asterisks appear for a few seconds around the center of the display. These asterisks indicate the position where the materials are presented. Next, pushing the space-bar causes the Context to appear, which is presented all together in two lines. Then, the Target is made to appear but this is presented word by word by pushing the space-bar for each word. After the presentation of the last word, the Question and Answer appear.

To start off, the subjects were told that the aim of this experiment was to investigate how quickly and accurately they comprehend the sentences. They were then given the instruction written in Japanese and were allowed to query when they were uncertain regarding the procedures. In order to ensure the instructions, they were told that they should comprehend the Context and Target as quickly as possible and answer the Question immediately after the presentation of the last word.

Response time was measured to the nearest 10 ms by each word in the Target. The answers to the question (whether 1 or 2) were also recorded.

Results and Discussion
Figures 1-8 show the results of the English major and non-English majors, respectively, in which the axes of the abscissa indicate the mean response time (ms) and axes of ordinate indicate the position of the word in the Target. The three lines correspond to the VP-biasing, NP-biasing and Neutral context, respectively. A one-way ANOVA was conducted across the three kinds of context at position three. It was also conducted between the English majors and non-English majors at each position. Table 1 shows the percentage of responses to the question by each context in each Target. Notice that in each context, the percentage for Answer 1 and Answer 2 sum up to 100.

A glance at these figures reveals that throughout the four materials, a great deal of response time is required at the last word (number eight). This is seen both in English majors and non-English majors, and is compatible with the result of native speakers (Boland, et al, 1989). Overall, the VP-biasing context took a longer response time than the other contexts. However, no significant difference was observed across the three kinds of context.

The figures also reveal that the response time is slightly greater at positions three and six. This tendency is observed to be slightly stronger in non-English majors than English majors but no significant difference is observed between them. Note, however, that this tendency is not observed in native speakers. (Boland et al., op. cit.) In the present study, significant differences across the three kinds of context were observed: Target 1, position three for non-English
majors \(F(2, 35) = 5.547, p < 0.01\), and Target 1, position six for English majors \(F(2, 33) = 3.389, p < 0.05\). Although non-English majors are seen to take a longer response time than English majors at three positions, no significant difference is observed between them. Notice that position three corresponds to the verb and position six to the preposition, and these two positions work crucially in sentence processing.

The answers to the question reveal that the preference toward the VP attachment is observed in Target 4. Regarding Target 1, no preference is observed. These tendencies can be seen most easily in the Neutral context. Thus it can be said that non-native speakers do not always prefer the VP attachment (often called "minimal attachment"), which is preferred by native speakers (Frazier & Fodor, 1978). Notice, however, that when two prepositions modify the noun phrase (e.g., He put the triangle next to the circle below the square.), native speakers show preference toward the NP attachment for both phrases (Langendoen, 1989).

**Table 1** The percent of responses to the Question by each Context in each Target

<table>
<thead>
<tr>
<th>Target</th>
<th>Context</th>
<th>Answer</th>
<th>Choice Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>EM</td>
</tr>
<tr>
<td>1</td>
<td>Ne</td>
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<td>50.0</td>
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<tr>
<td>1</td>
<td>Ne</td>
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<td>1</td>
<td>VP</td>
<td>1</td>
<td>60.0</td>
</tr>
<tr>
<td>1</td>
<td>VP</td>
<td>2</td>
<td>40.0</td>
</tr>
<tr>
<td>1</td>
<td>NP</td>
<td>1</td>
<td>20.0</td>
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<td>1</td>
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<td>Ne</td>
<td>1</td>
<td>100.0</td>
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<tr>
<td>2</td>
<td>Ne</td>
<td>2</td>
<td>0.0</td>
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<tr>
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<td>VP</td>
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</tr>
<tr>
<td>4</td>
<td>NP</td>
<td>2</td>
<td>100.0</td>
</tr>
</tbody>
</table>
To determine whether the context affects the sentence processing, the percentage of response to the question in Target 1 would be useful, since they are identical in the Neutral context. Here, the percentage of the VP attachment increases in the VP-biasing context whereas in the NP-biasing context the percentage of the NP attachment increases. Also, even in Target 2 and 3, which show high-biasing toward the VP attachment in the Neutral context, the percentage of NP attachment increases in the NP-biasing context. The reason for the high-biasing may be due to the semantic feature or argument structure of the verb. For example, the verb 'hit' usually requires something to hit with, which would induce the VP attachment more easily than the NP attachment. Anyway it can be said that for non-native speakers of English, contextual information affects the processing although in a slight degree.
Figures 1-8. Mean Response Time (ms) in Experiment 1 (left: EM; right: NEM)
( ▲ VP-biasing context, ■ NP-biasing context, ● Neutral Context)

Experiment 2

Subjects
Nineteen Japanese university students (10 males and 9 females) learning English as a foreign language served as participants. They ranged in age from 19 to 27 years (mean age: 21.2 years). None of them were reported to have speech or visual disorders. Since the difference in the proficiency of English was not seen in Experiment 1, English majors and non-English majors were combined here.

Stimulus Sentences
Three target sentences including (1) NP₁ and NP₂’s NP₃, (2) VP + Relative-Clause + Adv., and (3) Adj. + NP₁ and NP₂. The main criterion in preparing these sentences was that they could be interpreted twofold depending on the manner of attachment. The first construction can be interpreted as [[NP₁] and [NP₂’s NP₃]] or [[NP₁ and NP₂]’s [NP₃]]. The second construction can be interpreted twofold depending on whether the sentence-final adverb is included in the relative clause. The third construction can be interpreted as [[Adj. + NP₁] and [NP₂]] or [[Adj. + NP₁] and [Adj. + NP₂]]. A minor criterion was that the words used should show high familiarity for Japanese students.

Procedure
The procedures were the same as in Experiment 1.

Results and Discussion
Figures 9-11 show the results of Experiment 2, in which the axes of the ordinate indicate the position of the word in the target. Three lines correspond to the Neutral context, Context A
and Context B, respectively. A one-way ANOVA was conducted across the three kinds of context at each position. Table 2 shows the percentage of responses to the question by each context in each Target. Notice that in each context, the percentage for Answer 1 and Answer 2 sum up to 100.

Figure 9 reveals that a great deal of response time is required at position four across the three kinds of context. This tendency is observed more strongly in Context A than in the other contexts. This result shows that the [[NP$_1$] and NP$_3$'s] [NP$_3$]] construction is more difficult to parse than the [[NP$_1$] and [NP$_3$'s NP$_3$]] construction. It also reveals that the response time increases at position six for the biasing Context B and the Neutral context. Significant differences were observed between the Neutral context and Context A $[F(1,33)=4.457, p<0.05]$, and between Context A and Context B $[F(1,32)=4.958, p<0.05]$ at position two.

Figure 10 reveals that throughout the three kinds of context, a longer response time is required at the last word (number eight). This tendency is observed to be much stronger in biasing Context B than in the other contexts. Thus it can be said that the sentence-final adverb following the relative clause is processed easily as an internal element of the relative clause. A significant difference was observed between the Neutral context and Context B at position two $[F(1,35)= 4.957, p<0.05]$.

Figure 11 reveals that the response time is greater at position five across the three kinds of context. It also reveals that a great deal of response time and a longer total reading time are required at position four in biasing Context A. A significant difference was observed across the three kinds of context at position one $[F(2,48)=3.803, p<0.05]$.

The answers to the question reveal that the extent to which the context affects parsing depends on syntactic constructions. Target 1, in any context, shows high-biasing toward the interpretation of [[NP$_1$] and [NP$_3$'s NP$_3$]]. This tendency indicates that the subjects do not immediately utilize syntactic structure, that is, that the use of syntactic construction occurs only when the parser encounters NP$_5$. Also, little context effect was observed in this construction.

### Table 2. The percent of responses to the Question by each Context in each Target

<table>
<thead>
<tr>
<th>Target</th>
<th>Context</th>
<th>Choice Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Answer1</td>
</tr>
<tr>
<td>1</td>
<td>Ne</td>
<td>73.7</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>94.7</td>
</tr>
<tr>
<td>1</td>
<td>B</td>
<td>89.5</td>
</tr>
<tr>
<td>2</td>
<td>Ne</td>
<td>57.4</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>52.6</td>
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<td>2</td>
<td>B</td>
<td>42.1</td>
</tr>
<tr>
<td>3</td>
<td>Ne</td>
<td>26.3</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>68.4</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>10.5</td>
</tr>
</tbody>
</table>

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The percentage of responses in Target 2 are almost identical in each context, show that few context effects were observed. Also, even in Target 3, which shows high-biasing toward the \([\text{Adj.} + \text{NP}_1]\) and \([\text{Adj.} + \text{NP}_2]\) interpretation increases in biasing Context A.

Fig. 9-11. Mean Response Time (ms) in Experiment 2  
(▲ Neutral Context, ■ biasing context A, ● biasing context B)

Conclusion

The result in Experiment 1 has revealed that the preference toward VP attachment is not always observed in Japanese students. It has also revealed that a slight degree of context effect is observed. However, it has been found that English majors and non-English majors differ little in processing strategies. The result in Experiment 2 has revealed that context affects sentence processing differently, depending on syntactic structure.

For further study, the following should be taken into consideration: 1) use of an equally-biased Target in the Neutral context, 2) change of the length of noun phrase, both in subject and object positions, 3) employment of auditory presentation.

References


**Appendix A. Materials for Experiment 1**

[1] The policeman saw the spy with a telescope.
   Ne: The spy had escaped from the prison. The policeman pursued the criminal.
   VP: The spy had escaped from the prison. The policeman took something along.
   NP: The spy had escaped from the prison. He had something with him.
   QA: Who had a telescope?  1) the policeman  2) the spy

   Ne: My father and the man were carpenters. They began to quarrel with passion.
   VP: My father and the man were carpenters. My father grasped a tool quickly.
   NP: My father and the man were carpenters. The man was using a tool.
   QA: Who had a hammer?  1) my father  2) the man

   Ne: The man and the woman were old friends. They were planning to meet again.
   VP: The man and the woman were old friends. The woman was taking a rest.
   NP: The man and the woman were old friends. The man was drinking iced coffee.
   QA: Who was in the teahouse?  1) the woman  2) the man

[4] The boy found the girl in the cafeteria.
   Ne: The boy loved the girl very much. They were going to marry.
   VP: The boy loved the girl very much. The boy was having lunch.
   NP: The boy loved the girl very much. The girl was a waitress.
   QA: Who was in the cafeteria?  1) the boy  2) the girl
Appendix B. Materials for Experiment 2

[1] NP and NP’s NP: John and Dick’s father went skiing in winter vacation.
   Ne: Skiing is a very popular winter sport. It is exciting to ski down.
   A: Skiing is a very popular winter sport. John and Dick are good friends.
   B: Skiing is a very popular winter sport. John is a good brother of Dick.
   QA: How many people went skiing? a) one  b) two

   Ne: Roy lent me a novel. It was written in very easy English.
   A: Roy lent me a novel. I read it through in one night.
   B: Roy lent me a novel. It took two weeks to read it.

   Ne: A party was held last Sunday. A lot of people wanted to attend the party.
   A: A party was held last Sunday. Women who were over forty could attend the party.
   B: A party was held last Sunday. Anyone who was under thirty could attend the party.
   QA: Were the women young? a) No  b) Yes