# 14 Sentence Processing

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## 0 Introduction

The field of Japanese processing can be broadly divided into two subfields: word processing (i.e. lexical processing) and sentence processing. The former deals with questions such as how the meaning of a word is retrieved from the lexicon, how the lexicon is organized, and whether or not different orthographies constitute different processing routes. The latter focuses on questions such as how a sentence is parsed, how lexical and syntactic ambiguities are resolved, how a gap is filled in a sentence, and why certain sentences are more difficult to process than others. These are also general questions which one can raise during the investigation of any language and their answers help us understand how the human brain functions.

The above questions become more pertinent cross-linguistically when one considers whether there is a universal processing mechanism in the human brain. While constructing a universal processing model has so far been the predominant approach in the field, one major problem is the fact that universal processing theories were originally constructed solely on the basis of English data. When researchers tried to apply these theories to Japanese, they could not account for Japanese data.[1] We will discuss this in this chapter.

Although the focus of this chapter is Japanese sentence processing, we will first discuss lexical processing briefly because these two subfields are interrelated. For instance, a native speaker of Japanese can recognize words (i.e. can distinguish a word from a nonword in Japanese) very quickly. This suggests that the brain of a native Japanese speaker has a very efficient information retrieval system. Understanding how this system operates is important to understanding how a Japanese comprehends or produces sentences, because the meaning of a sentence requires retrieving information about each word contained in the sentence. The comparison of lexical processing at the word and the sentence levels allows us to understand how the lexical information retrieval system works in addition to making clear other aspects involved in sentence processing. Assuming that the relation between the grammar and the processing mechanism is transparent, understanding how the sentence processing mechanism operates helps us formulate a theory of grammar which is psychologically real. In this view, one can say that the processing mechanism shapes grammar or grammar shapes the processing mechanism, depending on one's point of view.

Understanding an adult's processing mechanism further relates to understanding the language acquisition mechanism. Research questions, such as what the initial state of the processing mechanism is and how children use their parser when formulating their grammar, allow us to understand the initial state of the language faculty and how one's grammar develops. Furthermore, all of the above questions can be addressed to language-impaired subjects as well. The comparison of data from both normal and language-impaired subjects provides us further insights into issues of how the human brain functions. Thus, the processing field is closely connected with theoretical linguistics, language acquisition, neurolinguistics, and other fields included in cognitive science, all of which open a door to the understanding of the human mind.

This chapter is organized into four sections: in section 1, I will briefly discuss the Japanese writing system. Many studies in lexical processing are closely related to issues in Japanese orthography, which is also pertinent to the discussion of sentence processing, since many sentence processing experiments involve reading. In section 2, I present a brief examination of lexical processing. Theories and experiments of sentence processing will be discussed in section 3. During the discussion, I will refer to different processing models and important aspects of the Japanese language which create problems for English-based processing theories. In the final section I will offer concluding remarks. Due to the limitation of space, I cannot exhaustively list or discuss all previous studies. Readers are referred to Kess and Miyamoto (1994) for additional references in Japanese psycholinguistics.

## 1 The Japanese Writing System

There are two kinds of characters in Japanese, *kana* and *kanji*, beside *roomaji* or romanization. *Kana* is a moraic script form, and there are two kinds, *hiragana* and *katakana*. In present-day Japanese, *hiragana* (cursive *kana*) is primarily used to indicate high-frequency morphemes such as postpositions and inflectional endings. *Katakana* (square *kana*) is used for all loanwords except those of Chinese origin. It is also used for emphasis (e.g. onomatopoetic words and foreigners' conversations in comics). Since these script forms are moraic, their script–sound correspondence is highly regular. There are 46 basic *kana* (71 with the use of diacritics, used for voicing, for example). *Kanji* or Chinese characters, on the other hand, do not have regular script–sound correspondences. They are primarily used for nouns, the roots of adjectives, and verbs. There are 1,945 daily-use *kanji* (or *jooyoo kanji*), most of which are taught during the nine-year compulsory education. Normally, both *kana* and *kanji* are used together in a sentence, although one can in principle choose to write a sentence using only *kana* or romanization. For instance, the same sentence can be written in four ways as shown in (1).

(1) a. Jon-ga hon-o yomu.
John-Nom book-Acc read
"John reads books."
b. じょんがほんをよむ。
c. ジョンガホンヲヨム。
d. ジョンガ本を読む。

Sentence (1a), which is written in *roomaji*, can be written in *hiragana, katakana*, and mixed script (*hiragana*, *katakana*, and *kanji*) as in (1b–d), respectively. The standard way of writing is (1d), in which the noun corresponding to John is written in *katakana*, *hon* "book" and a part of the root of the verb *yom* "read" in *kanji*. Case particles *ga* and *o*, and a part of the root of the verb and tense inflection *mu*, are in *hiragana*. Although the actual root of the verb "read" is *yom*, the *yo* portion is written in *kanji* while *mu* is written in *hiragana* because the readings of *kanji* and *kana* are moraic. Sentences are written vertically (top-down, right to left) or horizontally (left to right, top-down). Generally speaking, vertical writing is more formal and often employed in newspapers and formal letters and documents (Shibatani 1990), while horizontal writing is often found in contemporary governmental documents and scientific work. Horizontal writing is frequently found in readings in social and natural sciences.

Using three different scripts seems complicated enough, but what makes it truly complicated is the fact that there are different readings for each *kanji*. For instance, the *kanji* 行 has three different Chinese readings (*koo*, *gyoo*, and *an*) as shown in (2). Notice also that (2a) and (2b) are an example of homography.

(2) a. 一行(ikkoo) "accompanied group of people"
b. 一行(ichigyoo) "one line"
c. 行灯(andon) "lantern"

These three Chinese readings (*On-yomi*) were brought into Japan from China during three different time periods. In addition, this *kanji* has Japanese readings (*Kun-yomi*) such as "i/yu" as in 行く(i/yu-ku) "go" and "okona" as in 行う(okona-u) "conduct." This means that there are more than four readings for this *kanji*. See Shibatani (1990) on the history of *kanji* and *kana*.

The reading of *kanji* becomes even more complex when the regular reading does not apply to a compound word, a phenomenon known as *jukujikun* (熟字訓). Examples are shown in (3).

(3) 今日(kyoo) "today," 紅葉(momiji) "maple," 大人(otona) "adult"

The Japanese reading is given to a compound word which consists of two or more than two *kanji* characters. Each character often relates to the meaning of the word. For instance, the first character of *kyoo* means "now" and the second character means "day." Hence, the word is "today."[2] In these *jukujikun* cases, one can guess the meaning of words although one may not know how to read them.

Just the opposite of *jukujikun* is *ateji* (当て字), in which the reading of each *kanji* character was borrowed regardless of the meaning of the *kanji* character. Examples are in (4).

(4) 丁度(choodo) "exactly," 矢張(yahari) "as I thought"

Each character of these compound words retains its regular reading. However, their meanings do not obviously constitute or relate to the compound word's meanings. For instance, in the first word, *choo* is a counter and *do* means "degree" in (4). The two characters of the second word mean "arrow" and "paste, affix, or extend," respectively. Unlike *jukujikun*, one can apply regular readings to these *kanji* and understand the meanings of the words.[3]

Not every *kanji* character has more than one reading. The number of readings depends on the individual *kanji*. Therefore, native speakers of Japanese as well as non-native speakers must learn how to read *kanji* on a case-by-case basis. Because of the complicated physical composition of *kanji* characters and their multiple readings, many researchers are engaged in the investigation of the visual recognition process of *kanji* (e.g. Flores d'Arcais and Saito 1993, Flores d'Arcais et al. 1995) and the *kanji* acquisition process by children and L2 learners (e.g. Flaherty 1991, J. Yamada 1992). However, one of the most explored aspects of Japanese orthography has been how both *kana* and *kanji* are processed. We will now turn our discussion to this issue. For more about the Japanese writing system, see M. Paradis et al. (1985), Shibatani (1990), and Taylor and Taylor (1995).

## 2 Lexical Processing: Direct and Indirect Access

In previous studies on visual word recognition in Japanese, there have been two views on the relationship between script forms and word meanings, namely, direct and indirect access to word meanings. Direct access means that word meanings are directly retrieved from the visual representation of the words without phonological mediation. Indirect access means that phonological mediation is used. Since *kana* has a regular script–sound correspondence, many researchers have proposed that it is likely to need indirect access (i.e. phonological mediation). On the other hand, *kanji* may take the direct route because they do not have obvious regular script–sound correspondences (i.e. word meanings are directly retrieved from the visual representation of the words without phonological mediation). Evidence that the two scripts are accessed differently can be found in the aphasic literature. Impairment of *kana* processing, for instance, has been reported in Sasanuma and Fujimura (1971) among aphasic subjects with the additional symptom of apraxia of speech (see also Sasanuma and Fujimura 1972, Sasanuma 1974, 1980, 1984) and impairment of *kanji* processing was found among *gogi* (word-meaning) aphasics in Sasanuma and Monoi (1975) (see also Imura 1943). The findings in aphasics indicate that the readers use different routes to access the lexicon depending on the script types. Morton and Sasanuma (1984) suggest that *kanji* access the lexicon by their physical form alone (i.e. visual route), while *kana* require the reader to recode phonologically (i.e. phonological route) before the access occurs.[4]

However, it has been reported that both *kana* and *kanji* words have direct and indirect access to meaning. For instance, Besner and Hildebrandt (1987) report that words normally written in *katakana* were named (i.e. read aloud) more quickly among normal subjects when presented in *katakana* than either *katakana* nonwords or *kanji* words presented in *katakana*. Response times (i.e. the duration of the presentation of the word and the onset of naming) for *katakana* nonwords set baseline data since it requires phonological recoding. Since response times for *katakana* words were faster than those that involved the phonological recoding process, it was interpreted that *kana* can access the lexicon directly. Thus, Besner and Hildebrandt conclude that orthographically familiar *kana* words can achieve lexical access on the basis of orthographic code without recourse to phonological recoding. Similar conclusions are found in Hirose (1984, 1985) and Sasanuma et al. (1988).

As for *kanji*, phonological processing is also observed in Horodeck (1987), Wydell et al. (1993), Leong and Tamaoka (1995), and Matsunaga (1995a, 1995b), among others. For instance, Wydell et al. (1993) claim that reading *kanji* is characterized by parallel access to semantics from orthographic and phonological representations. Matsunaga (1995a, 1995b) reports that Japanese readers noticed both homophonic and nonhomophonic *kanji* errors, but that they noticed nonhomophonic errors more frequently than homophonic errors. Furthermore, Kondo and Kakehi (1994) find no difference between *kanji* and *kana* for the interaction between auditory and visual processing, and Gashuu (1994) reports that a familiar *kanji* character is as easily pronounced as *hiragana*. These all suggest that a dual or parallel approach is most plausible.[5] They also suggest that lexical access is very much influenced by the familiarity of the orthographic representation of a particular word.[6]

The role of orthographic familiarity in the processing of Japanese nouns is examined in Darnell et al. (1994) by using a word-by-word reading paradigm. In this task, each word was presented and replaced by another word as soon as a subject pushed a button. In their experiments, the familiarity of *kana* and *kanji* words (i.e. *hiragana* and *kanji* dominant words) in sentences was controlled and their contextual bias was manipulated. That is, the words lexically associated with the target words were presented before the targets in the contextually biased sentences (i.e. semantic priming). They find that (i) the orthography does not affect the reading time unless the sentence is contextually biased, in which case the most familiar orthography is faster; and (ii) *kanji* and *kana* can be processed at the same rate if familiarity is controlled or contexts are nonbiasing.[7] On the basis of these findings, Darnell (1995) compares the logogen model (Morton 1969), the search model (Forster 1976), and the connectionist model (Seidenberg and McClelland 1989) and concludes that the connectionist model can account for the Japanese data more easily.[8]

In sum, the previous findings indicate that any lexical processing model should allow for the dual processing of both *kana* and *kanji*. However, many research questions remain unanswered. For instance: how does *kanji*'s visual lexical access differ from that of other symbols'? How is lexical access in isolation different from in a sentence? When familiarity is controlled, is there any difference in the response time of the lexical decision task (i.e. the judgment as to whether or not what is presented is a word in the language) in terms of the numbers of moras and characters? How do phonetic and semantic primings affect lexical access? Answers to these questions would bring us a better understanding of how lexical access works.[9] I will come back to these research questions in my concluding remarks.

## 3 Sentence Processing

The field of Japanese sentence processing is still young and more work must be carried out in order to understand how the human brain processes Japanese sentences. However, recent developments provide us with many exciting findings. They have a direct impact on the theory of a universal human language comprehension mechanism.[10] Since most research has been conducted on reading, not listening, our discussion will focus on the findings in reading, although we will refer to some auditory work, where relevant. It is important to note that the test sentences are visually presented with both *kana* and *kanji* in the reading experiments in order to achieve a natural presentation for native speakers.

The task of structure building, i.e. building from a sequence of words to a syntactic representation of how these words are combined, is often called sentence or syntactic parsing. Thus far, the majority of research has been on parsing, although there are different aspects that can be investigated in sentence processing. Therefore, our discussion is also limited to parsing. There are three basic parsing models to which we refer from time to time below. They are a serial model, a parallel model, and a delay model. A serial model builds a single phrase structure as each word comes by (i.e. online) and a parallel model computes all possible structures with equal speed and ranking (i.e. the preference of the structures built). A delay model does not compute any syntactic structures until enough information is provided. Strict versions of these models and any parsing theory developed based on English all have difficulty dealing with the following characteristics of Japanese: (i) it is a head-final language, (ii) it has no relative pronouns, (iii) it has empty pronouns, and (iv) it allows scrambling. I will discuss these points in sections 3.1 through 3.4.

Particular sentence types, garden path and filler-gap sentences, will be referred to in sections 3.5 and 3.6. Sentence (5a) is a well-known English garden path sentence from Bever (1970: 316) and (5b) is an English filler-gap sentence from Frazier et al. (1983: 203).

(5) a. The horse raced past the barn fell.
    b. Everyone liked the woman $who_i$ the little $child_j$ started [$PRO_j$ to sing those stupid French songs for $[t]_i$ last Christmas].

In sentence (5a), a parser (or a syntactic processor) processes words from left to right and considers all elements up to *the barn* as belonging to one sentence with the main verb *raced*. However, when it proceeds to *fell*, it realizes that *fell* is the main verb. When the parser makes a wrong guess, it has been led up the garden path. So it is forced to reanalyze the sentence structure. When a sentence with a temporal ambiguity causes a problem for the parsing mechanism, it has a garden path effect. This implies that the parser makes its decisions incrementally online (i.e. in real-time processing) as the words are received. This suggests the plausibility of a serial processing model. We will look at what kind of garden paths are possible in Japanese and how different models can account for the different garden path effects. See Mazuka and Itoh (1995) for the term "garden path."

The examination of filler-gap sentences allows us to look at how a filler and a gap are linked online. For instance, the filler-gap sentence (5b) contains two different types of gaps (or empty categories), PRO and [t], which are coindexed with their fillers (or antecedents), *the little child* and *who*, respectively. Since *the little child* is interpreted as the subject of *sing*, it is coindexed with the empty subject PRO, and the relative pronoun *who* is related to the gap [t] (trace). To have the correct interpretation, the parser must appropriately locate those gaps and link them with the correct fillers. We will look at how the filler-gap relationship operates in Japanese.

## 3.1 Japanese, a head-final language

It has been considered that English is a head-initial language while Japanese is a head-final language. Consider the sentences in (6).

(6) a. John [ate an apple].
    b. John-ga [ringo-o tabeta].
       John-Nom apple-Acc ate

As shown in (6a), the verb (i.e. the head of the verb phrase) precedes the direct object in English (SVO word order). However, it follows the object in Japanese as in (6b) (SOV word order). This means that the verb which carries the complement information, i.e. subcategorization information, comes first in English, whereas in Japanese it comes at the end of the sentence. This raises the following question: does a Japanese parser wait for the verb in order to build phrase structures while reading? The head-final characteristic of Japanese creates many ambiguities before the verb because the parser cannot figure out how phrases are combined. Although case particles such as *-ga* (Nominative marker), *-ni* (Dative marker), *-o* (Accusative marker), and *-no* (Genitive marker) indicate grammatical functions and help the parser figure out the structure (e.g. A. Inoue 1991, Yamashita 1994, 1997a, 1997b, A. Inoue and Fodor 1995, Mazuka and Itoh 1995, Walenski and Sakamoto 1997), some syntactic ambiguities do not disappear. Consider the following.

(7) a. John-ga Mary-ga . . .
b. [John-ga [Mary-ga ringo-o tabeta to] itta]
John-Nom Mary-Nom apple-Acc ate that said
"John said that Mary ate an apple."
c. [John-ga Mary-ga suki-da]
John-Nom Mary-Nom like
"John likes Mary."

When one reads the sentence from left to right up to *Mary-ga* as in (7a), one cannot simply assume that both *John-ga* and *Mary-ga* are the subjects of different clauses as in (7b). This is because the object of the stative predicate can also take *-ga* as in (7c). That is, when we disregard the discourse context, we can never know which path (7a) will take. Then, what does the parser do?

The parsing model that has been referred to as a serial model builds the phrase structure as each word comes along. If the structure is built incorrectly, the parser must reanalyze the sentence according to this model. On the other hand, the parsing model that does not compute any syntactic structures until enough information is provided is called a delay model. A strict serial model predicts that processing Japanese is difficult because it requires reanalyses due to the structural ambiguities as we saw in (7). On the other hand, a strict delay model does not face this problem because the structure is not built until the combination of the words becomes clear. However, the delay model may cause memory overload because the sentence can be long. Considering the problem the serial model poses, Prichett (1988, 1991, 1992), for instance, proposes a somewhat restricted delay model, which is called a Head-Driven Parser. In this head-driven model, the head projects or builds the structure up to its maximal projection. For example, *Mary-ga* and *ringo-o* are combined with *tabeta* only when the verb *tabeta* is processed in (7b). Since the parser waits until the head, it does not require as much memory as does the strict delay model, which waits until *itta* in (7b) (cf. M. P. Marcus et al.'s 1983 D-theory model).

Another approach that takes into consideration the head-initial vs. head-final structural difference is discussed in Frazier and Rayner (1988), Mazuka and Lust (1989, 1990), and Mazuka (1990, 1998). These studies suggest that the parsing mechanism is affected by a head-initial vs. head-final parameter setting in the grammar. For instance, Mazuka (1990) claims that bottom-up (creating a phrase structure from the word level to the higher S-node level) and top-down (creating a phrase structure from the higher S-node level to the word level) organization of processing strategies is associated with the grammatical parameter setting of left- and right-branching languages. In other words, the parser does not experience difficulty as a consequence of the parameter setting in Universal Grammar when children start forming a grammar. Since subordinate clauses branch out leftward in Japanese and rightward in English, the parser takes the bottom-up and the top-down structure building strategies, respectively. This means that there are two ways the parsing mechanism works.[11]

These theories were proposed because previous theories formulated based on English predicted that Japanese would be quite difficult to process, but in reality, it is not. Berwick and Fong (1995) report that the head-final characteristic alone does not cause much difficulty to the parser, but it is a combination of different characteristics such as empty pronouns and scrambling in Japanese which produces parsing difficulties. We will look at these issues in sections 3.3 and 3.4 below.

## *3.2 No relative pronouns*

Japanese does not have relative pronouns (such as English *who*). This makes processing of Japanese relative clauses different from processing those of English. Furthermore, Japanese does not have different verbal endings in matrix and relative clauses as in Korean. Consider the following sentences. Sentences in (9) and (10) are Japanese and Korean counterparts of the English sentences in (8), respectively. The Korean sentences are from Yamashita (1994: 47–8).

(8) a. John gave Mary an apple.
b. John saw [the child [who gave Mary an apple]].

(9) a. John-ga Mary-ni ringo-o ageta.
John-Nom Mary-Dat apple-Acc gave
b. John-ga [[Mary-ni ringo-o ageta] kodomo]-o mita.
John-Nom Mary-Dat apple-Acc gave child-Acc saw

(10) a. John-i Mary-eykey sakwua-lul chuwo-ssta.
John-Nom Mary-to apple-Acc gave
b. John-i [[Mary-eykey sakwua-lul chwu-n] ai-lul] powassta.
John-Nom Mary-to apple-Acc gave-Rel child-Acc saw

As seen in (9b), Japanese does not have a relative pronoun equivalent to English *who* in (8b). Since there is no relative pronoun between *ageta* "gave" and *kodomo* "child," it is not clear if *ageta* is the verb in the matrix or relative clause. In addition, unlike the Korean sentences in (10b), Japanese verbal endings do not differ depending on whether the verb appears in the matrix or relative clause.[12] This makes the reader not certain if *ageta* is the matrix verb or the relative verb (i.e. the verb in the relative clause). Japanese verbs also do not show gender, person, and number agreement with the subject. This is shown in (11).[13]

(11) a. Mary-ga John-ni ringo-o ageru.
Mary-Nom John-Dat apple-Acc give
"Mary gives John an apple."
b. Boku-ga Mary-ni ringo-o ageru.
I-Nom Mary-Dat apple-Acc give
"I give Mary an apple."
c. Boku-to John-ga Mary-ni ringo-o ageru.
I and John-Nom Mary-Dat apple-Acc give
"John and I give Mary apples."

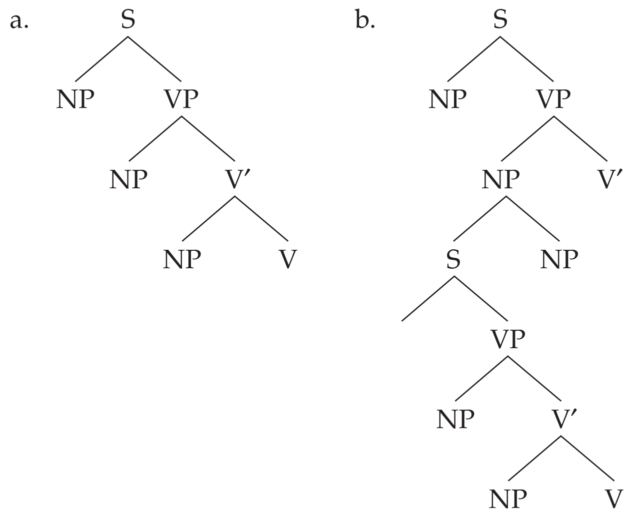
The lack of agreement in verbal morphology poses another problem for the theory of parsing. For instance, when the parser comes to the verb *ageru* "give" in (12a), it cannot tell if the sentence will end like (12b) or continues like (12c).

(12) a. John-to Bill-ga Mary-ni ringo-o ageru.
John and Bill-Nom Mary-Dat apple-Acc give
b. John-to Bill-ga Mary-ni ringo-o ageru.
"John and Bill give/will give Mary an apple."
c. John-to Bill-ga [[Mary-ni ringo-o ageru] kodomo]-o kimeru.
John and Bill-Nom Mary-Dat apple-Acc give child-Acc decide
"John and Bill decide the child who gives/will give an apple to Mary."

If the parser is building a single structure as it processes each word (i.e. an online serial processing model), it creates a complete simple sentence structure at the verb. However, if (12a) continues like (12c), then it is required to change the structure that has been built. That is, *John-to Bill-ga* is no longer the subject of *ageru*, and it has to be removed from the clause that contains *ageru*. In addition, the subject gap within the relative clause must be created in the structure so that it can be coindexed with the head of the relative clause, i.e. *kodomo*.

In this kind of serial model, the parser processes words from left to right online and attaches the coming word to the previously built structure. For instance, Frazier and Fodor's (1978) parsing model called the Sausage Machine employs the Minimal Attachment strategy for structure building. In this strategy, the structure building/attachment is accomplished with the creation of the smallest number of nonterminal nodes. So when the parser is processing (12a), it builds a simple ditransitive structure since creating an alternate relative clause structure requires more nodes (cf. Kimball 1973, Frazier 1978, Frazier and Rayner 1982, Ferreira and Clifton 1986). This can be seen in rough structures in (13), where the ditransitive structure is (13a) and the relative clause structure is (13b).[14]

(13)




Extending this idea, A. Inoue (1991) proposes the Information Paced Parser, which is a left-to-right, online, serial model with a look-back (i.e. it checks the analysis at the verb and the head NP of a relative clause). Minimal Attachment is operative in this model, but since the information that the parser receives at each point of decision making (i.e. the ambiguous point) is less than that in English, a Japanese parser is less confident. This model is later modified as a Ranked Flagged Information Paced Parser (Inoue and Fodor 1995). In this model, the parser records what alternative parses are and how highly the alternative is valued (flagging). The most heavily weighted flag is parsed first and the decision is made with a confidence proportional to what kind of information the parser received concerning the structural choice and the necessity of reanalysis. For instance, the main clause analysis (12b) is taken as the first parse, but as soon as the relative head noun *kodomo* is read in (12c), the relative clause analysis is taken. This means that although the parser takes the main clause analysis up to the point of the verb *ageru* in (12), it does not strongly commit itself to that particular analysis because of the possibility of the relative clause analysis.

A strict parallel model requires all possible structures to be computed with equal speed and weight, and sent to the semantic module (Altmann and Steedman 1988, but cf. Gorrell 1989, Gibson 1991, Hickok 1993, and MacDonald et al. 1994). Thus, in the case of Japanese, it would create a memory overload due to an overwhelming number of possible structures (particularly in Altmann and Steedman's model). However, a Ranked Parallel Model (Kurtzman 1985, Gorrell 1987) provides possible structures only in the ambiguous region (not every word) and hence restricts the number of structures computed. In Gorrell's model, the computed structures are ranked based on complexity (i.e. the simpler, the higher ranking) and the highest-ranked structure is passed to the semantic processing system first. This model is different from the above-mentioned Ranked Flagged Information Paced Parser in that the former builds the alternate structures while the latter does not. But they are the same in that they both require some memory (i.e. the former needs to keep all alternate structures whereas the latter keeps track of the flags). According to Yamashita (1994), who examines both Japanese and Korean relative clauses employing a lexical decision task (i.e. judging whether or not a particular word presented is a real word) and a grammatical judgment task (i.e. judging whether or not the sequence of the words is grammatical), a serial model with a tentative attachment more accurately accounts for both Japanese and Korean data. See also Hirose and Chun (1998), Hirose and Inoue (in press), and Kamide and Mitchell (1997). At this point in the research, however, it is not clear whether one of these models is substantially superior.

Although the structural ambiguity in the relative clause sentences is found in reading, Venditti and Yamashita (1994) claim that listeners reliably predict the structural difference even before the end of clause is revealed. For instance, they contrasted the following four types of sentences (1994: 376).

(14) a. Mari-ga [e] yonda.
Mari-Nom read
"Mari read (it)."

b. [Mari-ga [e]$_i$ yonda] hakusho$_i$-wa omokatta.
Mari-Nom read report-Top heavy was
"The report which Mari read was heavy."

c. [Mari-ga [e]$_i$ [e] yonda] hanare$_i$-wa kurakatta.
Mari-Nom read room-Top dark was
"The room in which Mari read (it) was dark."

d. [Mari-ga [e] yonda] handan-wa tadashikatta.
Mari-Nom read decision-Top correct was
"The decision due to Mari's reading (it) was correct."

Sentence (14a) is a simple sentence with an empty object (see section 3.3 below) while (14b–d) contain complex NPs, i.e. NPs with the argument relative clause and the PP adjunct relative, and the "pragmatic" complex NP (or NP with the gapless relative clause), respectively. All of these sentences include the sequence *Mari-ga yonda* "Mari read." Venditti and Yamashita report that there are robust acoustic differences between simple sentences and subordinate clauses of complex NPs in Japanese, i.e. sentence (14a) vs. (14b) through (14d). Those differences come from different prosodic structures of the two constructions. This suggests that there is online information, namely prosody, which plays a large role in cueing the intended structure of a segmentally ambiguous phrase. Therefore, what is predicted in reading may not actually happen in listening. See also Kondo and Mazuka (1996) and Misono et al. (1997) for prosody.

It is worthwhile mentioning another experimental finding on complex NPs here. Yamashita (1995) examines the following three different types of complex NPs: a gapless complex NP, an adjunct PP relative, and an argument relative.

(15) a. [Yuumei-na haiyuu-ga nesshin-ni shashin-o totta] sakuhinshuu-ga
famous actor-Nom ardently photo-Acc took collection-Nom
saikin chuumoku-sareta.
recently attention-was-paid
"The collection of the photos the famous actor took recently attracted attention."

b. [Yuumei-na haiyuu-ga nesshin-ni $[e]_i$ shashin-o totta] kooen$_i$-ga
famous actor-Nom ardently photo-Acc took part-Nom
saikin chuumoku-sareta.
recently attention-was-paid
"The park where the famous actor took the picture recently attracted attention."

c. [Yuumei-na haiyuu-ga nesshin-ni kooen-de $[e]_i$ totta] shashin$_i$-ga
famous actor-Nom ardently park at took photo-Nom
saikin chuumoku-sareta.
recently attention-was-paid
"The photos that the famous actor took at the park recently attracted attention."

(15a) is an example of a pragmatic complex NP, in which the embedded clause does not contain any gaps, but is pragmatically associated with the head noun *sakuhinshuu* "collection." On the other hand, (15b) and (15c) are instances of the adjunct PP and the argument relative clauses, respectively. All these sentences are similar in that the Minimal Attachment strategy discussed above does not predict any differences in them. Examining the self-paced reading times of these sentences, Yamashita (1995) finds that the verb's argument information is utilized very quickly in Japanese. The effect of the verb information was observed outside the clause, though there was no significant effect inside the clause. That is, as soon as the head noun is read, the gap is created if it is required by the verb in the relative clause. According to Yamashita, the verb argument information functions as an important source of information in online processing and the difference between English and Japanese is that in Japanese both overt and empty arguments are counted and the parser keeps track of them; if all the arguments are in the clause, the parser expects to end the sentence there. See also Yamashita et al. (1993) for these three types of complex NPs, and Horii (1990) for relative clauses with Ga/No conversion.

Another important study on relative clauses concerns center embedding. For instance, Mazuka et al. (1989) find that the reading time per character for (16b) is longer than that for (16a).

(16) a. Hiroshi-ga [Masao-ga katta] pan-o tabeta.
Hiroshi-Nom Masao-Nom bought bread-Acc ate
"Hiroshi ate the bread Masao bought."
b. Yoko-ga [Hiromi-ga [Asako-ga kaita] genkoo-o
Yoko-Nom Hiromi-Nom Asako-Nom wrote draft-Acc
kakinaoshita] shorui-o yonda.
rewrote paper-Acc read
"Yoko read the papers that Hiromi rewrote based on the draft Asako wrote."

Sentence (16a) contains one relative clause while (16b) has two relative clauses, creating the center embedding structure (as the clausal brackets indicate). This processing difficulty appears to be related to the complexity of the structure and memory. For accounts of the processing difficulty, see Gibson (1991), Babyonyshev and Gibson (1995), R. L. Lewis (1996), and Uehara (1997).

## 3.3 *Empty pronouns*

There are different kinds of empty categories. Recall sentences (14a) and (14b) and consider them with (17).

(14) a. Mari-ga [e] yonda.
Mari-Nom read
"Mari read (it)."
b. [Mari-ga [e]$_i$ yonda] hakusho$_i$-wa omokatta.
Mari-Nom read report-Top heavy was
"The report which Mari read was heavy."

(17) a. Mari-ga kyoo-no shinbun-o yonda.
Mari-Nom today-Gen newspaper-Acc read
"Mari read today's newspaper."
b. [e] kyoo-no shinbun-o yonda.
today-Gen newspaper-Acc read
"She read today's newspaper."
c. [e] [e] yonda.
read
"She read it."

A relative clause contains an empty category (or a gap) that is associated with the head noun. This is shown in (14b). In addition to this type of the empty category, there is another type as seen in sentence (14a). This empty category is not coindexed with anything. Its reference is taken extrasententially, unlike the empty category in the relative clause. For instance, suppose the context for (14a) is like (17a). When it is clear what Mari read, the object may be unpronounced as in (14a). This empty object is pronominal in nature and called an empty pronoun (often written as pro). Japanese allows such empty pronouns in both the subject and the object positions as is demonstrated in (17b) and (17c).[15]

In order to observe the complexity that empty pronouns raise, consider the sequence in (18a) and possible structures (18b) through (18h).

(18) a. John-ga Mary-ni ringo-o . . .
John-Nom Mary-Dat apple-Acc

b. [John-ga Mary-ni ringo-o (ageta]).
John-Nom Mary-Dat apple-Acc (gave)
"John (gave) Mary an apple."

c. [John-ga Mary-ni ringo-o (Bill-ga Sue-ni
John-Nom Mary-Dat apple-Acc (Bill-Nom Sue-Dat
orenji-o ageta]).
orange-Acc gave)
"John (gave) Mary an apple (and Bill gave Sue an orange)."

d. [John-ga [[[e]$_i$ Mary-ni ringo-o (ageta] kodomo$_i$-ni]
John-Nom Mary-Dat apple-Acc gave child-Dat
orenji-o ageta]).
orange-Acc gave
"John (gave an orange to the child who gave) Mary an apple."

e. [John-ga [[e] Mary-ni ringo-o (ageta] to itta]).
John-Nom Mary-Dat apple-Acc gave that said
"John (said that he gave) Mary an apple."

f. [[e] [John-ga] Mary-ni ringo-o (ageta] to itta]).
John-Nom Mary-Dat apple-Acc gave that said
"(He said that) John (gave) Mary an apple."

g. [John-ga Mary-ni [[e] ringo-o (katta] to itta]).
John-Nom Mary-Dat apple-Acc bought that said
"John (told) Mary (that he bought) an apple."

h. [John-ga Mary-ni [[e] [[e]$_i$ ringo-o (katta] kodomo$_i$-ni]
John-Nom Mary-Dat apple-Acc bought child-Dat
orenji-o ageta] to itta).
orange-Acc gave that said
"John (told) Mary (that he gave an orange to the child who bought) an apple."

The sentences in (18) maintain the basic word order and all share the sequence (18a). (18b) is a simple monoclausal sentence. (18c) is a coordinate structure. (18d) shows a relative clause in which the empty category is coindexed with the head noun. (18e) through (18g) contain complement clauses, but (18e) and (18g) differ depending on what type of verb follows *ringo-o*. In these sentences, the empty categories are empty pronouns. (18h) also shows another possible relative clause structure containing two empty categories, one of which is an empty pronoun and the other of which is an empty category that is coindexed with the incoming head noun *kodomo*. The structures in (18b) through (18h) are only some of the possible structures which might occur when one or two verbs, with or without an empty category, appear in a sentence following the sequence (18a). Imagine how many possible structures must be postulated before the end of the sentence if the parser uses a strict parallel model. It would have to postulate an enormous number of logically possible structures for the portion of (18a) shared by (18b) through (18h). Such a model would hardly account for Japanese sentence processing. See Mazuka (1991) on processing empty categories.

## 3.4 Scrambling

We have seen the head position and empty categories create potential problems to a parsing theory. According to Berwick and Fong (1995), empty pronouns and scrambling, in addition to the head position, provide even greater challenges to processing theories. So let us look at scrambling here. Observe the sentences in (19).

(19) a. John-ga ringo-o tabeta.
John-Nom apple-Acc ate
"John ate an apple/apples."
b. Ringo-o John-ga tabeta.
apple-Acc John-Nom ate
c. $[_S$ Ringo$_i$-o $[_S$ John-ga $[_{VP}$ $[e]_i$ tabeta]]]

Sentence (19b) is a scrambled counterpart of (19a): the order of the subject and the object is reversed. It has been argued that the structure of (19b) is reflected by (19c), which contains the empty category (i.e. trace) coindexed with the preposed object (cf. Saito 1985).

Scrambling increases the structural ambiguity of the sentence. For instance, the following structure becomes possible for (18a) in addition to (18b) through (18h). In sentence (20), [t] indicates a trace (i.e. an empty category) of the scrambled element *ringo-o*.

(20) [John-ga Mary-ni [ringo$_i$-o (Bill-ga $[t]_i$ katta] to itta])
John-Nom Mary-Dat apple-Acc Bill-Nom bought that said
"John (told) Mary (that Bill bought) an apple."

Scrambling takes place in the complement clause in (20). Even when *Bill-ga* is read after *ringo-o*, there is no guarantee that the sentence ends like (20) because of the possibility of (18c). Now we can clearly understand why strict serial, delay, and parallel models all have difficulty accounting for Japanese sentence processing.

Although we have mentioned that scrambling creates ambiguities, Yamashita (1997a) claims that the parser is tolerant of scrambling. In a self-paced reading experiment, she found no extra processing load in reading scrambled sentences. In addition, no effect of word order was found on the parser in making syntactic decisions before reaching the verb in the experiment with the lexical decision task. On the other hand, the parser seemed sensitive to Case marking, identifying the grammatical functions of the parsed elements (see also Yamashita 1997b). These results suggest that what we predict theoretically seems different from the empirical findings.

Another interesting experimental finding on scrambling is presented in M. Nakayama (1995). The author reports that scrambled elements do not seem to create traces at the level of representation where empty categories (anaphorically dependent elements) access their antecedents. This finding is different from other types of empty categories such as empty pronouns and NP-traces (cf. M. Nakayama 1990, 1991). If scrambling does not leave a trace, the structure of (19b) is not reflected by (19c) and it suggests that as long as the verb and its arguments are linked together, the order of the arguments does not matter. We will come back to this issue in section 3.6 below (also see Prichett and Whitman 1995 and Ichio 1997).

## *3.5 Garden path effects and parsing models*

If scrambled sentences do not create an extra processing load, the head-final characteristic and empty categories still seem to challenge the parsing theories that have been proposed based on English. Although English-based parsing theories predict processing difficulties in Japanese, the predicted difficulty is often undetected in online experiments. However, some sentences are found to be difficult to process. We now turn the discussion of sentences with different degrees of difficulty (i.e. garden path effects). First, let us consider Nagata's (1993) sentences with giving and receiving verbs (i.e. *kureru* and *ageru/yaru*). For giving and receiving verbs, for instance, see Kuno (1973) and Tsujimura (1996b). The *kureru* sentences were originally considered as garden path sentences by Mazuka et al. (1989).

(21) a. Koochi-ga kantoku-ni hinansareta toki bengoshite kureta.
coach-Nom manager-by criticized was when defend gave
"When I was blamed by the manager, the coach spoke up for me."
b. Koochi-ga kantoku-ni hinansareta toki bengoshite yatta.
coach-Nom manager-by criticized was when defend gave
"When the coach was blamed by the manager, I spoke up for him."

The sentences in (21) are the same except for the last verbs, *kureta* in (21a) and *yatta* in (21b), but their interpretations are very different as their translations indicate. Their rough structures can be shown with the brackets as in (22).

(22) a. [Koochi-ga [ [e] kantoku-ni hinansareta toki] [e] bengoshite kureta]
b. [[Koochi-ga kantoku-ni hinansareta toki] [[e] [e] bengoshite yatta]]

Both sentences require two empty pronouns, but what these refer to differs due to the nature of the verbs. *Kureru* requires the referent of its object noun to be "in-group," i.e. the speaker or someone related to the speaker, while *ageru/yaru* does not. Therefore, the two empty pronouns are interpreted as the speaker in (22a) while the empty subject and object are interpreted as the speaker and the coach, respectively, in (22b). The postulation of these empty categories and their interpretations become possible only when the parser reaches the verbs *kureta* and *yatta*. Assuming online serial processing, the preferred structure of *Koochi-ga kantoku-ni hinansareta toki* is that of (22b). Thus, (22b) is considered as the non-garden path control sentence. In Nagata's experiments, the subjects were asked to identify the subject of the verb (either *hinansareta* or *bengoshite*), which was presented after the end of the sentence with different intervals. The higher error rate was observed in the garden path sentences such as (21a) even when the verb was presented four seconds after reading the sentences. That is, (21a) is more difficult to parse than (21b). It was also found that the parser was not able to immediately reconstruct the previous syntactic structure, requiring a certain period of time to reach a final decision. Although this was Nagata's interpretation of the results, he himself questions whether this kind of experimental task reveals the nature of syntactic processing. We will return to this issue in the next section, but for now, suffice it to say that making the subjects answer such questions seems to tap into offline semantic processing, not online syntactic processing. If this is indeed correct, then it is difficult to estimate what degree of difficulty *kureru* sentences create in online syntactic processing.

Mazuka and Itoh (1995) discuss different degrees of reanalyses in garden path sentences.[16] For instance, the sentences in (23) are examples of noncostly reanalysis while (24) and (25) exemplify costly reanalysis. A costly reanalysis here means that a different structural analysis must be taken and the change from the old structure to the new one involves difficulty for the parser.

(23) a. [Hiroshi-ga [[e]$_i$ Masao-o mita] otoko$_i$-o . . .
Hiroshi-Nom Masao-Acc saw man-Acc
"Hiroshi . . . the man who saw Masao . . ."
b. [Hiroshi-ga [[e]$_j$ [[e]$_i$ Masao-o mita] otoko$_i$-o
Hiroshi-Nom Masao-Acc saw man-Acc
yobidashita] onna$_j$ . . .
called woman
Hiroshi . . . the woman who called the man who saw Masao . . ."

(24) a. [Yooko-ga kodomo-o koosaten-de mikaketa]
Yoko-Nom Child-Acc intersection at saw
"Yoko saw the child at the intersection."
b. [Yooko$_i$-ga kodomo-o [[e]$_i$ [e]$_j$ koosaten-de mikaketa]
Yoko-Nom Child-Acc intersection saw
takushii$_j$-ni noseta
taxi-Dat put-on
"Yoko put the child in the taxi which she saw at the intersection."

(25) a. Mukoogawa-o [osu-to mesu]-no nihonzaru-no shashin-ga . . .
over there-Acc male and female-Gen monkey-Gen picture-Nom
". . . the picture of the male and female monkey . . . over there . . ."
b. [[e] Mukoogawa-o osu-]to mesu-no nihonzaru-no shashin-ga
over that side-Acc push if female-Gen monkey-Gen picture-Nom
demasu
appear
"If you push the other side, the picture of the female monkey appears."

(23b) requires reanalysis after creating a structure like (23a). The parser needs to construct an additional relative clause. However, since *Masao-o mita otoko* is intact, the revision is not costly. On the other hand, (24b) requires reanalysis from the simple clausal structure (24a) to the relative clause structure with two empty categories. Since *kodomo-o mikaketa* is not intact, it is costly. Sentences in (25) involve lexical ambiguity. *Osu* is taken as the noun "male" in (25a) but as the verb "push" in (25b). Because of the different categories, the lexical homonyms create a costly reanalysis.[17] See Mazuka et al. (1997) on the experimental results of the lexical homonym sentences.

Although the question of how garden path effects differ must be determined experimentally, let us assume different degrees of processing load in the above garden path sentences. Those differences must be explained by the parsing model. As we discussed in the previous section, a strict serial model fails to differentiate the different degrees of garden path effects (cf. deterministic models in M. P. Marcus 1980 and Berwick and Weinberg 1983; but see M. P. Marcus, et al. 1983 and Weinberg 1995 for different kinds of deterministic models). Neither a strict delay model nor a strict parallel model can account for the different degrees of garden path effects. A. Inoue's (1991) and A. Inoue and Fodor's (1995) Ranked Flagged Information Paced Parser as a serial processing model and Prichett's (1988, 1991, 1992) Head-Driven Parser as a delay model are all modified models that account for Japanese data, but they are by no means problem-free. Mazuka and Itoh (1995) employ a serial model with a tentative attachment strategy and attempt to explain the different degrees of the effects. That is, each node attachment is temporal during the structure building process (cf. Yamashita 1994). All of these models attempt to explain the different garden path effects, but it is not clear how each precisely calculates the cost for each of the garden path sentences considered.

A different approach is taken in Fodor and Inoue's (1994) Diagnosis Model. It suggests that the recovery from the garden path consists in repairing the structure that was built rather than reparsing the input. In order to repair it, the parser must diagnose its error. If the error is clear from the nature of the symptom (i.e. if the error signaled by the incoming word is incompatible with the structure built), recovery is easy and less costly. This model assumes that the first- and the second-pass parses do not differ fundamentally, but revision difficulty varies depending on the symptom. Consider the following "double relative" sentence (originally from A. Inoue 1991: 71).

(26) Mary-ga shinseihin-o kaihatsushita amerikajin-ga
Mary-Nom new product-Acc developed American-Nom
keieishiteiru mise-ga tsubureta.
be running shop-Nom went bankrupt

a. "*Mary, the shop which the American who developed the new product runs went bankrupt."
b. "The shop which an American runs, where Mary developed the new product, went bankrupt."

Sentence (26) means (26b). The (26a) interpretation is not possible. However, the first reading one takes is (26a). This shows a severe garden path effect. The parser starts building the sentence structure from the first word and when *amerikajin-ga* is reached, it reanalyzes the previous clause *Mary-ga shinseihin-o kaihatsushita* as the matrix subject (*Mary-ga*) and a relative clause (*shinseihin-o kaihatsushita*) modifying *amerikajin*. Furthermore, *shinseihin-o kaihatsushita amerikajin-ga keieishiteiru* becomes another relative clause that modifies *mise*. However, this structural analysis fails when the parser faces *tsubureta*. This verb is an intransitive verb, taking *mise* as its subject. Now *Mary-ga* is left out. It cannot be attached to anything. This is the reading (26a). Since it is not a possible interpretation, the parser tries to find another way.

The difficulty of (26) suggests that building a coordinate structure or raising a relative clause appears to be costly. However, it is not always so, suggesting that raising operations are not inherently costly for revisions. Consider the following sentences from Fodor and Inoue (1994: 423).[18]

(27) Oosama-ni-taishite burei dearu kokkai-giin-ni-taishite burei dearu
king-Dat-against rude is diet-member-Dat against rude is
otoko-ga okotta.
man-Nom became angry

a. "The man who was rude to [the member of parliament who was rude to the king] became angry."
b. "The man [who was rude to the member of parliament] (and) [who was rude to the king] became angry."

(28) Oosama-ni-taishite burei dearu kokkai-giin-ni-taishite-mo burei
king-Dat-against rude is diet-member-Dat-against also rude
dearu otoko-ga okotta.
is man-Nom became angry
a. ??"The man who was rude to [the member of parliament who also was rude to the king] became angry."
b. "The man [who was rude to the member of parliament] (and) [who also was rude to the king] became angry."

Sentences (27) and (28) are different in that (28) contains *mo* "also" after *taishite* "against." These sentences have basic structures comparable to that of (26) (i.e. two relative clauses). Sentence (27) is ambiguous, but (28) is not. This suggests that changing from the relative clause analysis to the coordinated relative clause analysis is not inherently difficult. Then, why is (26) difficult? Fodor and Inoue claim that it is because detecting the symptom is difficult. In (28), there is *mo*, which is a symptom that allows the parser to diagnose the problem. Therefore, it is easier to reanalyze (28) than (26), which does not contain an apparent symptom. The idea that the presence or absence of the symptom (i.e. positive or negative symptom) affects the reanalysis is crucially different from other models. This diagnosis model predicts that revision difficulty can vary with the symptom. See also Hirose and Chun (1998).

## 3.6 *Filler-gap sentences*

Sakamoto (1991, 1995a, 1995b, 1996, 1997c) investigates Frazier et al.'s (1983) Most Recent Filler (MRF) strategy in Japanese control sentences (cf. English (5b)).[19] According to this strategy, a detected gap (an empty category) is initially and quickly taken to be coindexed with the most recent potential filler during comprehension. And in such a case, the parser does not recognize the empty category as a possible antecedent (the Lexical Fillers Only hypothesis, hereafter LFO). MRF and LFO make interesting predictions when applied to Japanese. Let us consider their predictions in two types of Japanese control sentences used in Sakamoto's experiments.

(29) a. Toshio$_i$-ga ototoi Junko-ni [PRO$_i$
Toshio-Nom the day before yesterday Junko-Dat
Tookyoo-iki]-o tegami-de hakujooshita.
Tokyo going-Acc letter-by confessed
lit. "The day before yesterday, Toshio confessed to Junko by mail that he would go to Tokyo."

b. Jiroo-ga senshuu Kazumi$_i$-ni [PRO$_i$ Tookyoo-iki]-o
Jiroo-Nom last week Kazumi-Dat Tokyo going-Acc
denpoo-de tanonda.
telegram-by requested
lit. "Last week, Jiroo requested of Kazumi by telegram that she go to Tokyo."

Sentences (29a) and (29b) are Subject and Object control sentences, respectively. The empty subject PRO of the nominal clause *Tookyoo-iki* is obligatorily interpreted (i.e. controlled) as the same referent as the subject in (29a) and as the object in (29b). That is, the person who goes to Tokyo is Toshio (the matrix subject) in (29a) but Kazumi (the matrix indirect object) in (29b).[20] In these sentences, the MRF strategy predicts that Junko and Kazumi will be the fillers of the gaps (PROs) because they are the closest fillers to the gaps in (29a) and (29b), respectively. If the MRF strategy is employed, (29a) evokes an incorrect answer to the question, "Who is supposed to go to Tokyo?"

Next, let us consider the scrambled counterparts.

(30) a. Junko$_i$-ni Toshio$_j$-ga ototoi [t]$_i$ [PRO$_j$
Junko-Dat Toshio-Nom the day before yesterday
Tookyoo-iki]-o tegami-de hakujooshita.
Tokyo going-Acc letter-by confessed
lit. "The day before yesterday, Toshio confessed to Junko by mail that he would go to Tokyo."

b. Kazumi$_i$-ni Jiroo-ga senshuu [t]$_i$ [PRO$_i$ Tookyoo-iki]-o
Kazumi-Dat Jiroo-Nom last week Tokyo going-Acc
denpoo-de tanonda.
telegram-by requested
lit. "Last week, Jiroo requested of Kazumi by telegram that she go to Tokyo."

(30a) and (30b) are scrambled counterparts of (29a) and (29b), respectively. The MRF strategy predicts that either Toshio and Jiroo or traces of Junko and Kazumi will be the fillers of PROs. Since the LFO hypothesis says that empty categories (traces) do not become potential fillers, only Toshio and Jiroo can be the fillers. Then, only (30a) evokes the correct answer to the above question. Because of scrambling, Japanese offers an interesting test to evaluate the MRF strategy and the LFO hypothesis.

Sakamoto presented these types of sentences and asked native subjects to name the person who was supposed to be in Tokyo as soon as they finished listening to them. He measured the time from the presentation of the end of the sentence to the voice onset. He found that their response times for Subject control sentences consistently were longer for both scrambled and unscrambled sentences. This means that scrambling had no effect. If the MRF strategy and the LFO hypothesis are correct, (30a) should not take longer than (30b).

Oda et al. (1997) and Ninose et al. (1998) used Sakamoto's test material with the dichotic listening task and found the opposite results. In their experiments, the subjects were requested to push either a yes or a no button after listening to the name of the person who was supposed to be in Tokyo. The response times for the Object control sentences were longer than those of the Subject control sentences for both scrambled and unscrambled sentence types. There were no scrambling effects in these studies, either.

In Frazier et al. (1983), the subjects were instructed to read the test sentences presented one word at a time on a cathode ray tube (CRT), and at the end of the sentence, they were required to answer whether they understood the sentence ("got it") or whether they had to go back and reread it ("missed it"). Their response times and the percentages of the sentences that were successfully understood were computed. Their experimental task was different from those of Sakamoto, Oda et al., and Ninose et al. Therefore, it may be possible that these different experimental tasks brought different results. In particular, Sakamoto's elicitation task seems to appeal more to semantic processing than to syntactic processing because the subjects must say the person's name instead of choosing yes or no as in Oda et al. and Ninose et al. The comparison of Mazuka et al. (1989) and Nagata (1993) also suggests that the elicitation task seems to tap on much deeper processing (not online syntactic processing). Since it is not clear what experimental tasks are appropriate for the aspects of processing one attempts to investigate, I leave my definite interpretation of the above findings on the Japanese filler-gap sentences for future research (cf. Walenski and Sakamoto 1997). However, their results at least suggest the following: (i) the MRF strategy and the LFO hypothesis seem incorrect, (ii) scrambling has a null effect, and (iii) different tasks bring different results.

Note that the above finding on scrambling is very important. Despite different experimental tasks, no scrambling effects were found in either experiment. As we discussed earlier, scrambling was assumed to increase the structural ambiguity and the processing load for the parser. However, the findings from these experiments as well as M. Nakayama (1995) and Yamashita (1997a) suggest that scrambled sentences are not processed differently from unscrambled sentences. This is an important finding for a theory of a universal human language processing mechanism. However, we must remember that this finding comes from the optional scrambling of sentences without any prior context. That is, short-distance (or clause-internal) scrambling in those sentences does not change the grammaticality or the meaning of the sentence. Therefore, to confirm the present finding, it is necessary to investigate cases in which scrambling changes the grammaticality and the meaning of the sentence as well as cases in which there is a discourse.[21]

# 4 Concluding Remarks

I have discussed various topics in the field of Japanese processing in this chapter. In lexical processing, I discussed lexical access by different script forms, *kana* and *kanji*. The current finding suggests that a correct lexical access model must allow for the dual processing of both characters. However, there remain many unanswered questions: how is lexical access in isolation different from that in a sentence? Does it bring any orthographic differences? Most of the previous experiments dealt with words in isolation. Therefore, it is important to find out how lexical access differs in isolation from that in a sentence. In this context, we also need to investigate how phonetic and semantic priming affect lexical access (see Ainsworth-Darnell 1998). In particular, semantic priming at the word level and at the sentence level would shed some light on how lexical access is done in a sentence. The question of how *kanji*'s visual lexical access differ from that of other symbols allows us to see the mechanism of visual perception and lexical access. When word familiarity is controlled, is there any difference in the response time of the lexical decision task in terms of the numbers of moras and characters? Can we obtain the same kind of results with different experimental tasks? Answers to these questions would bring us a better understanding of how lexical access works and the structure of the lexicon in our brains.

In sentence processing, we discussed different characteristics of Japanese that would bring processing difficulties to the strict serial, parallel, and delay parsing models theoretically. Given different degrees of garden path effects in Japanese sentences, a correct model must be one of those models with some modification. It must also account for differing degrees of difficulty. In relation to this, one must explore a theory of memory as well. There has been a claim that the source of the processing difficulty lies in memory (e.g. R. L. Lewis 1996). Therefore, the parsing mechanism together with the limitation of memory may possibly create differing degrees of difficulty. In addition, various studies find that there seems to be no difference between scrambled and unscrambled sentences. This is a very important finding in that it has a direct implication for a theory of grammar, assuming the transparency hypothesis, namely, that there is no trace of a scrambled element in the relevant structural representation. If one denies the transparency hypothesis, then one must answer the question of how the grammar and the processing mechanism interact. I have also discussed filler-gap sentences, in which I could not conclude how the control sentences are processed. Conflicting experimental results derived from different tasks in control sentence studies suggest that we need to find out what aspects of grammar a particular task is relevant to.

Finally, my discussion of sentence processing was limited to syntactic processing. This is because literature on semantic and pragmatic aspects of sentence comprehension and production is extremely scarce (cf. M. Walker et al. 1994). Therefore, keeping the above questions in mind, more experimental studies must be carried out which address different aspects of processing. Then, future research would certainly provide a much better understanding of how the language faculty is organized and how it functions (cf. Mazuka and Nagai 1995 and Sakamoto 1997a).

## NOTES

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commenting on the earlier version of this chapter. Any shortcomings are, of course, mine.

1 For a general history of processing theories in relation to the development of linguistic theories, see Carlson and Tanenhaus (1989) and Frazier (1991).

2 Note that the first two example words in (3) have regular readings, "konnichi" "these days" and "kooyoo" "red leaves/autumn colors." The third word, however, does not have another reading, though the meanings of the characters are "big" and "person."

3 When two *kanji* are combined to form a word, the possible reading patterns are four as shown below. In (ia), for example, both characters are given the Chinese readings; and in (ic), the first character has the Chinese reading while the second has the Japanese reading.

(i) a. Chinese–Chinese reading
古書 (kosho) "old books"
b. Japanese–Japanese reading
古里 (furusato) "hometown"
c. Chinese–Japanese (Juubako-yomi)
本箱 (honbako) "book shelf"
d. Japanese–Chinese (Yutoo-yomi)
古本 (furuhon) "used book"

4 See also M. Paradis et al. (1985). For involvement of the right hemisphere in semantic processing of *kanji*, see Aoki (1990).

5 As for *kanji* phonology, see Wydell et al. (1995) and for the relationship between the experimental tasks and results, see Gashuu (1994) and Hino and Lupker (1996).

6 As for the *kanji* familiarity, Amano and Kondo (1995) and Kondo and Amano (1996a) report that word familiarity ratings depend on the least familiar *kanji* in the word, and Kondo and Amano (1996b) claim that the familiarity ratings are correlated very weakly with the physical complexity of *kanji*. However, they found that the more complex *kanji* tend to be less familiar *kanji*. See also Kondo et al. (1996).

7 Their results need to be compared with those of the lexical access experiment that tests the same words in isolation.

8 Due to space limitations, I cannot discuss these models in detail here. Readers are encouraged to read the original papers cited in the text. However, very roughly speaking, the logogen model is the model that contains a feature recognizer (i.e. logogen) which represents various linguistic information (e.g. semantic and syntactic information) of a word, and it attempts to capture the different characters with the same feature specification. The search model contains one lexicon with the master file and three peripheral files: one organizing words by orthographic properties, one by phonological properties, and one by semantic and syntactic properties. Darnell (1995) points out that this model fails to account for the contextual bias. The connectionist model explains lexical processing via the activation of different nodes such as orthographic, phonemic, and semantic nodes, which have multiple levels of nodes that are all linked in a network. The information flows on the basis of how frequently the connection is used between the nodes. Thus, different accessibilities to particular information are explained.

9 For other research on orthography and lexical processing, for example, see Koda (1990), Wells (1995), and Chikamatsu (1996).

10 There are very few studies on production. See N. Iwasaki et al. (1997).

11 Mazuka's (1998) work is very important in that it addresses the relationship between the processing mechanism and how children shape their grammar. What is the initial state of the processing mechanism? When children do not have adult grammar or when they are formulating grammar, how do they use their parser? What kind of interaction do the processor and the grammar have? These are all serious questions to be answered by the theory of parsing. Although Mazuka attempts to answer these questions, it is not clear to me how her proposal works in detail. See also Weinberg (1993, 1995), Gorrell (1995), and A. Inoue and Fodor (1995), and N. Hasegawa's (1990) comments on Mazuka and Lust (1990).

12 See Yamashita (1994), Hirose and Chun (1998), and Hagstrom and Rhee (1997) for processing Korean relative clauses.

13 Note that the noun does not indicate number, either. This is observed in (11). There are some plural suffixes that can attach to nouns (e.g. *boku* vs. *boku-ra* or *boku-tachi*), which are only used with nouns that refer to people. However, these are not pure pluralizers as discussed in Tsujimura (1996b: 156 fn. 2) and S. Martin (1975). That is, one can say *Tanaka-tachi*, which means a group of people including Tanaka.

14 Although their precise structures may not be like those in (13), the point is clear in that the relative clause structure requires more nodes than the ditransitive structure.

15 Although there are other kinds of empty categories (e.g. PRO, NP-traces in passives and *wh*-traces in *wh*-questions), we will not go into them here. However, one of them (PRO) will be discussed in Section 3.6. Note that though there are different types of empty categories, there are a couple of characteristics that are common among them. One is that their existence becomes clear by information carried by other elements in the sentence. For instance, an empty pronoun is detected when one reads a transitive verb with one overt argument. It becomes clear by the verb's subcategorization. Thus, they are inferred indirectly. Another characteristic is that they all have their antecedents. They are referentially dependent elements (i.e. anaphoric expressions). For empty categories and sentence processing, see Fodor (1989).

16 As the word 'reanalyses" indicates, they assume a serial processing model. However, I am not certain if they consider that the parser repairs the previously built structure or the parser discards the structure built, but keeps it in memory as the unwanted structure and forces itself to construct another structure by reparsing the sentence.

17 If (25) is presented orally or *osu* is written in *kanji*, the lexical ambiguity does not occur in (25) because *su* in *osu* "male" is accented and written as 雄 or 牡 while *osu* "push" is unaccented and written 押す.

18 Fodor and Inoue's original examples did not contain *-ga* after *otoko*, which might be a typo.

19 By testing the MRF strategy in the control sentences, Sakamoto was also investigating the degree of transparency in the relationship between the mental grammar

and performance theory (i.e. Transparency Hypothesis). According to this hypothesis, the grammar–parser relation is neither equal nor independent, but is rather transparent (e.g. Berwick and Weinberg 1984). Although the results did not support the MRF strategy, they did not refute the hypothesis, either.

20 Sentences in (29) are slightly different from regular control sentences. For instance, (29a) can be paraphrased as follows.

(i) Toshio$_i$-ga
Toshio-Nom
ototoi
the day before yesterday
Junko-ni [PRO$_i$
Junko-Dat
Tookyoo-e iku koto]-o
Tokyo to go fact-Acc
tegami-de hakujooshita.
letter-by confessed
lit. "The day before yesterday, Toshio confessed to Junko by mail that he would go to Tokyo."

This sentence contains a clause with the Subject controlled PRO. If it does not contain the temporal phrase *ototoi* "the day before yesterday," the scrambled sentence will cause the following ambiguity.

(ii) a. Junko$_j$-ni Toshio$_i$-ga [t]$_j$ [PRO$_i$ Tookyoo-e iku koto]-o tegami-de hakujooshita.
"Toshio confessed to Junko by mail that he would go to Tokyo."
b. [e] Junko-ni [Toshio-ga Tookyoo-e iku koto]-o tegami-de hakujooshita.
"Toshio confessed to Junko by mail that he would go to Tokyo."

Sentence (iib) indicates that the sentence is not a Subject control sentence since there is no PRO in the embedded clause. Because of this ambiguity and the fact that the number of temporal phrases is limited, the scrambled counterparts of the regular control sentences cannot be tested. This is why Sakamoto uses nominal clause sentences. However, he did test the sentences with full clauses such as (i) in one of his experiments. See Sakamoto (1995c, 1997b) on the nature of Japanese control sentences.

21 Having said this, I realize that it is sometimes difficult to test these cases because of the lack of appropriate experimental control sentences against which those scrambling sentences can be contrasted. See Ichio (1997) on the acceptability test of long-distance scrambling sentences.