Processing sentences in Japanese

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1 Brief introduction

This chapter summarizes research investigating how sentences are processed in Japanese (Nakayama et al. in press, for a recent collection of papers on Japanese psycholinguistics, also Kess and Tadao Miyamoto 1994, for an extensive survey of early work). The goal in this field is to determine how people understand sentences by examining how they uncover the meaning intended as they read (or hear) each word. Ambiguity plays a central role. At each point in the sentence, how do readers choose among the alternative interpretations often available? What do those preferences tell us about the way grammatical knowledge (as well as world knowledge, social conventions) is put to use? What are the cognitive resources (e.g., working memory, attention) used and how do they shape this process?

2 Description of the core data

The simplest way to collect data on sentence comprehension is to ask readers to rate sentences (according to their naturalness, acceptability and so on). This type of questionnaire data is off-line as it only provides a measurement after reading of the entire sentence has finished. Although off-line results can provide critical information, they often have to be complemented with on-line studies in which measurements are taken as the sentence is being read.

2.1 Reading time measurements

The discussion will draw primarily from reports of reading experiments, in which similar sentences are compared and relatively longer reading times are taken as a sign of difficulty. In eye-tracking, eye movements are recorded every few milliseconds and measures of difficulty
include *fixations* (how long the eyes fixate in a word or sequence of words) and *regressions* (how often the eyes return to a prior region; Rayner 1998, for a summary).

Because eye-tracking requires special equipment and can be taxing on participants (accurate data collection may require participants’ heads to be kept immobile through the use of chin rests and bite-bars), computer-based methods are often used. In *self-paced reading*, participants press a button to see the next region of the sentence and the elapsed time between button presses is assumed to correspond to the reading time for that region. A region can include one or more words (usually one or more *bunsetsus* in Japanese) depending on the hypothesis being tested, but it is crucial that the segmentation is chosen carefully so that it does not lead to artificial breaks or groupings (words in a region tend to be grouped together during reading). Presentation can be *center-screen*, so that a new region replaces the previous region in the center of the screen at each button press. Or it can be of the *non-cumulative moving-window* type, in which case the whole sentence is presented masked with each character replaced with dashes or dots (in Japanese, spaces are used to indicate the segmentation), and for each button press a new region is revealed while all other regions remain masked. Although readers cannot return to previous regions, self-paced results (of non-cumulative moving-window in particular) are well correlated with eye-tracking data (Just, Carpenter and Woolley 1982).

To determine whether a word is read slowly in a given sentence, its reading times are compared to those of a word in a similar sentence. However, such comparisons are only meaningful if the words are similar in terms of length, part of speech, frequency, familiarity. Moreover, because readers may speed up as they read more words in the sentence, comparisons are preferentially made between words that occupy similar linear positions in the sentences.

In *rapid serial visual presentation* or RSVP, words are flashed on a computer monitor for short periods of time — around 350 ms per word in English, and 700 ms per bunsetsu in Japanese. The difference in presentation rates in the two languages is largely explained by
the fact that bunsetsus usually include a content word and a functional word. RSVP is particularly useful in brain imaging studies, in which participants are required to read sentences without moving their body (including hands and eyes).

2.2 Brain responses

Brain responses to be discussed are similar to the ones observed for other languages. For event related potentials (ERP), difficulty in integrating a word into the syntactic representation of the sentence (in syntactic violations in particular) leads to a P600 response (i.e., a positive deflection peaking 600 ms after the end of the ungrammatical word; e.g., after the declarative particle yo following a wh-phrase, Nakagome et al. 2001). Semantically unexpected words (e.g., dekaketa ‘went out’ in jisho-ni dekaketa ‘went out to a dictionary’) elicit an N400 (a negative response that peaks 400 ms after the offending word, Nakagome et al. 2001, also Kiguchi and Miyamoto 2004, for its localization using magnetoencephalography, MEG). Broca’s area, a brain region usually associated with grammatical functions (e.g., Sakai et al., 2002, and references therein for more specific localizations), is more active in functional magnetic resonance imaging (fMRI) during the processing of scrambling (Koizumi 2005) and center-embedding (Inui et al. 1998).

3 Working memory

Working memory (Baddeley 1992, for a summary, also Baddeley 2000, for recent developments, and Just and Carpenter 1992, Caplan and Waters 1999, for discussions specific to language processing) plays a role in much of the following discussions. Working memory is where information is held for short periods of time (roughly up to 2 seconds) in order for various types of cognitive tasks to be performed. It is severely constrained in the amount of information it can hold (consider how hard it is not to forget a phone number while dialing it). Item length is also important as the number of words that can be recalled decreases if the words are long. This word length effect indicates that one of the components of working memory is phonolog-
ically based (the other component handles visual information). The phonological nature of the encoding is further supported by the *phonological similarity effect* — it is harder to recall items that sound similar (e.g., the letters *PGTVCD* sound similar and are harder to recall than the dissimilar *RHXKWY*). The small capacity in working memory is compensated by *chunking* (Miller 1963), an operation to associate items together so that they occupy fewer slots in working memory. Consider how much harder it is to recall the sequence of ten digits 6-5-1-9-4-5-2-0-1-0 than the three numbers 65-1945-2010, or that it will be 65 years in 2010 since the end of World War II. A rough parallel can be drawn with sentence processing as we associate words together (e.g., a subject with a verb) creating links with our long term memory (e.g., that a war finished in 1945) in order to create a more abstract representation that occupies fewer slots so that we have more capacity to process upcoming words in the sentence.

### 3.1 Individual differences in working memory and in long term memory

Working memory capacity for reading has been measured using the *reading span task* (Daneman and Carpenter 1980) by determining the largest number of sentences a person is able to read aloud and later recall the last word for each one of them. Readers with different reading spans have been argued to display divergent reading patterns to filler-gap dependencies (King and Just 1991, but see Caplan and Waters 1999, for criticisms).

Using the Japanese version of the reading span task (Osaka 1998), in which the word to be recalled is not necessarily the last one in the sentence so that its part of speech can be varied, reading span has been shown to improve if the word to be recalled is the one regarded independently as being the most important in the sentence (Osaka et al. 2002).

While reading span reflects readers’ ability in handling transient information in working memory, reading also requires retrieving information from long term storage. In one such a measure, participants are shown words (written in kanjis) that are commonly used in Japanese
but rarely written in kanji (e.g., 彼は arekore ‘this and that’) and asked to write down their pronunciation (the Hyakurakan test, Amano and Kondo 1999). While reading span correlates poorly with vocabulary tests but correlates well with general reading abilities (as measured by multiple-choice university entrance examinations), Hyakurakan not only has a high correlation with vocabulary, it also has a higher correlation with reading abilities than reading span does (Jincho 2004).

4 Controversies

One basic question is how similar the processing of sentences is across different languages. One extreme view is that each language requires a specific processing algorithm apart from its own distinct grammar. In other words, not only is the grammar parameterized but also the way how people use the grammar to process sentences is different for each language. This approach raises issues in learnability (children have to set grammatical and processing parameters simultaneously, but see Mazuka 1998, for a constrained parameterization and its possible trigger, also Hasegawa 1990, Inoue and Fodor 1995, for criticisms of earlier versions of Mazuka’s proposal) and it is also conceptually more complex than its alternative, which is the null hypothesis often assumed in the field. In this other type of proposal, the assumption is that all that children need to set are the parameters in the grammar as the processing algorithm is universal to all languages (Fodor 1998).

4.1 Incremental processing

One central topic within the parameterization discussion is whether head-final languages like Japanese are processed incrementally, as is the case of head-initial languages, or whether comprehension lags behind the actual reading of the words in the sentence (Inoue and Fodor 1995, for discussion). The problem is clearest at the clausal level. In the following example, each individual NP can be created and interpreted immediately (i.e., there is ‘a student from Fukuoka’, and ‘a teacher’, and ‘a letter’).
(1) Fukuoka shussin-no gakusei-ga sensei-ni tegami-o

Fukuoka native-gen student-nom teacher-dat letter-acc

The question is to what extent the NPs are associated together as part of a single representation before the verb is seen. An incremental solution is to assume that case markers provide enough information for readers to understand that the student did something to the letter for the benefit of the teacher, although the exact action is not known. But that is enough to bind the NPs together in one single chunk by predicting an underspecified predicate (i.e., partial information about the predicate is used to project the necessary structure, e.g., a VP node, to associate the NPs; Den and Inoue 1997, Miyamoto 2002, Yamashita 2000, for related discussions).

In contrast, in head-driven models the lexical head has to be present in order for a node to be projected. This is sometimes justified as a strict adoption of Chomsky (1981)’s projection principle within performance (Pritchett 1991). As a by-product, processing must be non-incremental in Japanese as all arguments (and adjuncts) cannot be associated together until the verb is read as only then is the VP node created. Few experimental studies claim to support this type of model (e.g., O’Grady, Nakamura and Lee 2002, but the result is compatible with incremental models that adopt a proposal such as Gibson 1998) and most arguments have been conceptual (e.g., in a strict bottom-up model, ‘a node can be built only when all daughters of the node have been found’, Abney 1989; but see alternative algorithms in Abney and Johnson 1991) or based on problems with incrementality.

For example, it has been argued that case markers cannot aid in interpretation because they do not have a one-to-one correspondence with thematic roles (Pritchett 1991). However, it is known nowadays that lexical ambiguity does not prevent incremental interpretation. For example, when reading an ambiguous verb that allows more than one argument structure, English speakers assign a thematic role to a NP using the argument structure most frequently used with that verb (Garnsey et al. 1997). Similarly, Japanese speakers may interpret a case-marked NP
based on the most common use of that case marker with such a noun.

Head-driven models have serious problems of their own (Miyamoto 2002, for a discussion). For example, they predict a considerable memory load as arguments have to be memorized individually until the predicate is read, whereas in incremental models constituents are associated together and can occupy fewer slots in working memory (recall the discussion on chunking in Section 3). The burden implied by head-driven models should hinder acquisition in head-final languages (e.g., leading to shorter utterances) but such typological discrepancies have not been documented.

Apart from detailed discussions based on intuitive judgements (Inoue 1991), current evidence supporting incremental models include studies examining reading times (Kamide and Mitchell 1999) and ERPs (Oishi and Sakamoto 2004) to the clause-final predicate. More critical to the resolution of the controversy, various studies have examined reactions prior to the predicate. These include eye-movements while listening to sequences of NPs (Kamide, Altmann and Haywood 2003), ERPs for sequences of NPs (Garnsey et al. 2001) and for scrambled NPs (Ueno and Kluender 2003), reading times for scrambled NPs (Mazuka, Itoh and Kondo 2002, Miyamoto and Takahashi 2002a, 2004), for scrambled wh-phrases (Aoshima, Phillips and Weinberg 2004), for pronouns (Aoshima, Phillips, & Weinberg, 2003) and for sequences of case-marked NPs (Miyamoto 2002). Although each result considered individually is unlikely to settle the issue, taken together they make a strong case against a large class of non-incremental models. The following sections elaborate on two lines of evidence.

4.2 Anticipatory eye-movements

While listening to instructions (e.g., pick up the candy), English speakers’ eyes move to the relevant object about 145 milliseconds after the end of its name. Because 200 ms are necessary to execute eye movements, the result suggests that the decision to move the eyes can occur even before the end of the word is heard (Tanenhaus et al. 1995, also Mazuka et al. 2005, for
In a study investigating incremental processing, Japanese speakers heard sentences as in (2) while looking at a picture of a waitress, a client, a hamburger and other objects (Kamide, Altmann and Haywood 2003).

(2) a. Dative object condition

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Ueitoresu-ga kyaku-ni tanosigeni hanbaagaa-o hakobu.
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waitress-nom customer-dat merrily hamburger-acc carry
‘The waitress merrily carries the hamburger to the customer.’

b. Accusative object condition

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Ueitoresu-ga kyaku-o tanosigeni karakau.
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waitress-nom customer-acc merrily tease
‘The waitress merrily teases the customer.’

Until ‘merrily’, the sentences in (2) differ only in the case marker of ‘customer’. However, already by that point, participants had made more anticipatory eye-movements towards the hamburger while listening to the dative-object sentence in (2a) compared to when they heard the accusative condition in (2b) (Kamide, Altmann and Haywood 2003). The result suggests that the participants considered the hamburger a more natural continuation for the dative object. The result is unexpected if NPs were processed independently as argued by some non-incremental models.

4.3 Case markers as indicators of clause boundaries

But if processing is incremental in Japanese, the question is how readers interpret a sequence of NPs (and PPs) in relation to each other before the predicate is read. Because embedded clauses in Japanese do not have any markers to indicate their beginning (Inoue 1991, for a discussion), readers may not even know how many clauses there are in a sequence of NPs unless they read the sentence until the end. But under some circumstances, case markers can indicate where
clause boundaries lie. For example, in a sequence containing two accusative NPs, readers can assume that at least two clauses are necessary based on the double o constraint, according to which two accusative NPs cannot be in the same clause in Japanese (Harada 1973). In fact, long reading times can be observed at the second NP-o in such cases. That the long reading times are not simply a sign of surprise to an unusual sequence of NPs is suggested by faster reading times to the head of a relative clause later in the sentence (Miyamoto 2002). The result is compatible with the claim that the long reading times at the second accusative NP were used to create the initial boundary for an embedded clause, which facilitated processing at the head noun of the relative clause.

Furthermore, given the special properties of nominative NPs in Japanese (they cannot be scrambled, Saito 1985; they have to be associated with an inflected predicate, Takezawa 1987), it is possible readers use such NPs as anchors around which other NPs in the same clause are interpreted (Miyamoto 2002, also Uehara and Bradley 2002, Experiment 3, on the preference to have each animate nominative NP in a separate clause, and Mazuka, Itoh and Kondo 2001, for a P600 to nominative NPs). The use of case markers to determine clause boundaries is illustrated in the following example (from Kamide and Mitchell 1999).

(3) Kyooju-ga gakusei-ni toshokansisho-ga kasita komonjo-o miseta.

professor-nom student-dat librarian-nom lent manuscript-acc showed

‘The professor showed the manuscript that the librarian had lent to the student.’

As in its English translation, ‘student-dat’ in (3) is ambiguous and can be the recipient of ‘showed’ or ‘lent’. In a self-paced reading experiment, the ‘showed’ interpretation was found to be preferred, even though ‘student-dat’ is closer to ‘lent’ (Kamide and Mitchell 1999). Noting that no verb in Japanese can take the first three NPs as arguments, already at the third NP it is clear that at least two clauses are needed in this case. The result then can be explained if one assumes that there is a preference to insert a clause boundary where it is first clear to be
necessary (at ‘librarian-nom’) leaving ‘student-dat’ in the matrix clause where it attaches to the matrix verb (Miyamoto 2003, for discussion).

Another way of indicating the beginning of an embedded clause is to use numeral classifier mismatch as in the example below (from Yoshida, Aoshima and Phillips 2004).

(4) San-satu-no sensei-ga yonda hon . . .
   three-cl-gen teacher-nom read book
   ‘Three books that the teacher read . . .’

Because the numeral classifier *satsu* cannot be used to count people, it creates the prediction for an upcoming noun such as ‘book’, and the noun ‘teacher’ is taken to be the beginning of a relative clause (Yoshida, Aoshima and Phillips 2004).

Although particles are unlikely to be the only source of information (see Iguchi and Miyamoto 2006, Muraoka and Sakamoto 2003, on the role of animacy), the research above suggests how sequences of NPs can be interpreted in complex multiple clauses before the predicate is seen.

### 4.4 A single processing mechanism

The rest of this chapter will assume that processing is strictly incremental in Japanese and that there is a single processing mechanism that subserves the processing of all human languages. The goal then is to characterize this single processing mechanism and consider how its general properties are instantiated in Japanese. One line of research that can be pursued is to show that a strategy attested in various languages is also adopted in Japanese (e.g., for wh-phrases). Another possibility is to investigate apparent differences in the way Japanese is processed (e.g., in relation to relative clauses) and the challenges they raise for the assumption of a single processing mechanism.

### 5 Reanalyses of clause boundaries

In Section 4.3, some clause boundaries were claimed to be inferred from case markers. But in the absence of clause-initial markers, it is often the case that relative clauses are only detected
after the verb (but see Misono et al. 1997, Venditti in press, Venditti and Yamashita 1994, for prosodic cues in speech).

5.1 Subject reanalyses

Up to ‘delivered’ in (5a) (from M. Inoue 1990a), the single-clause interpretation ‘Taro delivered flowers to Masako’ is favored.

(5) a. Subject reanalysis

Taro-ga Masako-ni hana-o todoketa otoko-o tasikameta.
Taro-nom Masako-dat flower-acc delivered man-acc scrutinized
‘Taro scrutinized the man who delivered flowers to Masako.’

b. Taro-ga Masako-ni hana-o todoketa koto-ga wakatta.
Taro-nom Masako-dat flower-acc delivered fact-nom found out
‘It was found out that Taro delivered flowers to Masako.’

c. Masako-ni hana-o todoketa otoko-o Taro-ga tasikameta.
Masako-dat flower-acc delivered man-acc Taro-nom scrutinized
‘Taro scrutinized the man who delivered flowers to Masako.’

When the noun ‘man’ is read, the subject ‘Taro-nom’ must be reanalyzed out of the clause so that a gap can be created. A series of experiments by Masakatsu Inoue provide evidence for difficulty at the head noun. In an eye-tracking experiment, first-pass fixations were longer and more regressive eye-movements were observed at ‘man’ in (5a) compared to ‘fact’ in (5b) and ‘man’ in (5c) (M. Inoue 1990a). The cost to reanalyze ‘Taro’ out of the simple clause initially built for (5a) has also been reported for transitive and intransitive clauses replacing the embedded ditransitive clause headed by ‘delivered’ (M. Inoue 1990b). Furthermore, the finding that reading times to ‘man’ are shorter if Taro is marked with the topic wa (M. Inoue 1991) is compatible with the claim that because topicalized NPs are in the periphery of the clause and may only hold an aboutness relation with it, displacing them is relatively easy.
An fMRI study detected more activity in Broca’s area for subject reanalysis sentences such as (5a) compared to the left-branching (5c) with a transitive clause replacing the ditransitive embedded clause (Inui et al. 1998). The result was claimed to be due to the center-embedding configuration of (5a), but it is also possible that reanalysis contributed to the result.

5.2 Subject-object reanalyses

The sentences in (6) have been extensively compared (Mazuka and Itoh 1995, also Kondo and Mazuka 1996, for eye movements while reading such constructions aloud).

(6) a. Subject reanalysis

Yoko-ga kodomo-o koosaten-de mikaketa onnanoko-ni koe-o-kaketa.

Yoko-nom child-acc intersection-loc saw girl-dat called

‘Yoko called the girl who saw the child at the intersection.’

b. Subject-object reanalysis

Yoko-ga kodomo-o koosaten-de mikaketa takusii-ni noseta.

Yoko-nom child-acc intersection-loc saw taxi-dat put

‘Yoko, made the child get on the taxi she, saw at the intersection.’

Up to the verb ‘saw’ in (6a,b), the single clause interpretation ‘Yoko saw the child at the intersection’ is built. When a head noun is detected next, the simple clause must be reanalyzed to insert a gap for the relative clause. Mazuka and Itoh (1995), based on intuitive judgments, observed that reanalysis is harder in (6b) than in (6a) because of the number of arguments that have to be displaced in each case. In (6a), only the subject ‘Yoko’ is displaced to the newly built matrix clause, whereas in (6b) both ‘Yoko’ and the object ‘child’ have to be displaced. This observation has been discussed within various reanalysis frameworks (e.g., Gorrell 1995, Sturt and Crocker 1996).

Experimental work suggests that the difficulty in (6b) comes from the ambiguity in ‘taxi’ (it can be the object or the subject of ‘saw’) which hinders the reanalysis process (Hirose and
Inoue 1998). However, another self-paced reading study indicates that even with unambiguous head nouns, (6b) is still difficult to process (Miyamoto 2002).

Displacing more NPs is not always dispreferred. The two objects in ditransitive constructions can be displaced together in situations where displacing the accusative NP alone would be sufficient, thus arguing against proposals in which the amount of revisions is always minimized during reanalysis (Miyamoto 2003).

6 Implicit prosody in silent reading

The influence of prosody on the comprehension of utterances (Venditti in press, for a summary) has been recently expanded by claims that underlying prosodic contours influence processing decisions during silent reading as well (Fodor 2002). For example, a short modifier (‘kind’) is preferentially attached to the closer noun (‘student’), but a long modifier (‘extremely kind’) is preferentially attached to the farther noun (‘student’s sister’) so that the lengths of modifier and modifiee are similar (Hirose et al. 1998, Inoue and Fodor 1995).

(7) (kyokutanni) sinsetsuna gakusei-no imooto

extremely kind student-gen sister

‘(extremely) kind student’s sister’

Prosodic effects are also observed in the resolution of clause boundary ambiguities. Until ‘trusted’ in (8a,b)), a single clause interpretation is preferred.

(8) a. Single-name subject

Morisita-ga sinyaku-o kokorokara sinyoosita yuujintati-ni

Morisita-nom medicine-acc truly trusted friends-dat

b. Conjoined-name subject

Hosokawa-to Morisita-ga sinyaku-o kokorokara sinyoosita yuujintati-ni

Hosokawa-and Morisita-nom medicine-acc truly trusted friends-dat
c. . . . shohoosen-o okutta.

   prescription-acc sent

Single-name: ‘Morisita sent the prescription to the friends who really trusted the medicine.’

Conjoined-names: ‘Hosokawa and Morisita sent the prescription to the friends who really trusted the medicine.’

Reanalysis at friends can build two types of relative clauses (see Section 5.2). The object ‘medicine-acc’ can remain as part of the relative clause (the subject reanalysis) or be displaced to the matrix clause together with the subject (the subject-object reanalysis).

The nominative subjects in the fragments in (8a,b) differ in their lengths (as measured by the number of minor phrases or accentual phrases), which lead to different prosodic contours when read aloud. A major phrase boundary (also known as intermediate phrase) tends to be produced immediately after the conjoined names, whereas with the single-name subject it is produced after ‘medicine-acc’ (Hirose 2003, Experiment 2). Those two positions for the major phrase boundary correspond to the beginning of the embedded clause in the subject-reanalysis interpretation and the subject-object reanalysis respectively.

When asked to write sentences starting with the fragments in (8a,b), Japanese speakers’ completions display subject reanalysis interpretations more often with conjoined subjects (Hirose 2003, Experiment 1). This is compatible with the claim that speakers assign implicit prosodic contours while reading in silence and that the position of the major phrase boundary influences the insertion of the embedded clause boundary.

Furthermore, when (8a,b) are continued as in (8c), the matrix clause contains ‘prescription-acc’, thus only the subject-reanalysis interpretation is possible (two accusative NPs cannot be part of the same clause, hence ‘medicine’ has to be part of the embedded clause). For such sentences, readers take longer at ‘prescription-acc’ in the single-name subject condition than
in the conjoined-names condition. This suggests that ‘medicine’ is more likely to be displaced to the matrix clause in the single-name condition, where it clashes with ‘prescription’ (Hirose 2003, Experiments 4 and 5).

Prosodic contours have also been argued to influence the scope assignment of wh-phrases (see the chapter on wh-phrases in this volume).

7 Verb morphology

Apart from auxiliaries expressing empathy (e.g., kureru) and animacy (Nicol 1998, for production mistakes in animacy agreement with iru and aru), a number of studies have examined the morphology of verbal compounds.

7.1 Subject reanalysis with kureru

The auxiliar kureru at the end of (9) expresses empathy (i.e., who benefits from the action) and has been used to force subject reanalysis (Mazuka et al. 1989).

(9) Yuujin-ga moochoo-de nyuin-siteita toki mimai-ni kite-kureta.

friend-nom appendicitis-for hospitalized-was when visit-dat came

‘When I was hospitalized with appendicitis, my friend came to visit.’

The NP ‘friend’ is interpreted as the subject of ‘hospitalized’ until kureta signals that the speaker was the beneficiary of the visit. This forces a subject reanalysis to displace ‘friend’ to the matrix clause and insert a phonologically-null subject (identified with the speaker) in the embedded clause. Mazuka and colleagues did not detect difficulty for (9) (78% correct in truth-false judgements and whole-sentence reading times comparable to other sentences). However, in other studies, in which participants were given the embedded verb and asked to produce its subject, performance was at chance at the end of the sentence and only improved gradually thereafter (Nagata 1993).

7.2 V-te-V compounds

One of the studies on verbal compounds investigated sentences as in (10) (from Nakatani, 2006).
The critical words (from the dative NP until the last word shown in (10a,b)) were shown in one single region, for which reading times were longer in (10b) than in (10a) and other control conditions. The longer reading times for (10b) are expected because the NP-ni is far from ‘arrived’ given the intervening embedded clause. The result indicates that there is no embedded clause in (10a) and motte-kita is processed as a unit.

8 Filler-gap dependencies

The processing of filler-gap dependencies has been shown to underline a variety of phenomena across a number of different languages. The typical example is fronted wh-phrases in English as illustrated in the following sentence (adapted from Crain and Fodor 1985).

(11) Filled gap effect (FGE)

Who did the children force ∧ us to sing the songs for gap, last week?

The filler who in (11) triggers the search for a gap (the thematic position of the wh-phrase). As each word is processed, readers posit the gap at the earliest possible position, that is, at ‘∧’ as the direct object of force). A slow down occurs when the word us is read as it indicates that the position of the gap is incorrect (Crain and Fodor 1985). This type of filled-gap effect is evidence for strict incremental processing as the required gap is inserted without lookahead to check the next word in the sentence.
The preference to insert the gap as soon as possible is consistent with the claim that long dependencies consume cognitive resources such as working memory necessary to keep the filler and its gap requirement active until the gap position is found. In some models, this is a special case of a general phenomenon as readers are assumed to keep track of the syntactic heads necessary to complete the sentence. The number of heads predicted and the amount of material processed since each head was first predicted determine the memory cost at each point in the sentence. The idea is that the maintenance of each prediction consumes cognitive resources, thus the more predictions and the longer they are kept active in working memory, the more costly their processing (Gibson 1998, and references therein, see Babyonyshev and Gibson 1999, for a discussion on Japanese).

Much of the discussions in the following sections will revolve around filler-gap dependencies or generalizations of them.

9 Relative clauses

Cross-linguistic work on relative clauses has been particularly active in the investigation of gap position (the position that is relativized in the clause) and attachment ambiguities.

9.1 Relative clauses and gap position

The memory load imposed by long dependencies has also been used to explain why relative clauses with the gap in subject position are easier to understand than those with the gap in object position in a number of European languages (e.g., English, King and Just 1991; French, Holmes and O’Regan 1981).

(12) a. Subject-gap relative clause: the senator, that gap, accused the reporter

   b. Object-gap relative clause: the senator, that the reporter accused gap,

If distance between filler and gap is the critical factor in parsing relative clauses, object gaps should be easier to understand than subject gaps in prenominal relative clauses, contrary
to results in Japanese using questionnaires (Sheldon 1976) and self-paced reading (Ishizuka, Nakatani and Gibson 2003, Miyamoto and Nakamura 2003).

Interestingly, self-paced reading results for prenominal relative clauses in Mandarin Chinese have been claimed to favor gaps in object position (Hsiao and Gibson 2003; Hsu 2003, for criticisms), and data from aphasic patients indicate that object gaps are also easier in Cantonese (Law and Leung 2000). Thus, Japanese may be exceptional and its preference for subject gaps may be caused by the syntactic properties of its relative clauses (Miyamoto and Nakamura 2003, for discussion), which may also explain the availability of constructions usually not seen in other languages (e.g., Nakamura & Miyamoto, 2006, on double-gap relative clauses; Yamashita 1995, on gapless relative clauses; Yoshida and Sano 2001, on head-internal relative clauses).

9.2 Relative clause attachment

Another line of research started with the finding that when reading the daughter of the colonel who suffered the accident in their native language, speakers of English prefer the interpretation in which the relative clause attaches to the low noun in the tree structure (colonel), whereas in Spanish the high noun (daughter) is preferred (Cuetos and Mitchell 1988; see http://www.lingua.tsukuba.ac.jp/etm/rc/ for a list of results for various languages). In Japanese, questionnaires indicate that there is an overall preference for the high noun (Kamide and Mitchell 1997, Experiment 1, also Hirose 2001, Sturt, Branigan and Matsumoto-Sturt 1999). Reading times have also been measured for unambiguous sentences (disambiguated through plausibility manipulations) as in (13).

(13) a. High attachment

        [RC Hoosekibako-no sumi-ni nokotteita] hannin no simon o
jewelry-box-gen corner-loc remained criminal gen fingerprint acc
keisatu-ga nantoka mitukedasita.
police-nom somehow found
‘The police somehow found the fingerprint of the criminal that remained in the corner of the jewelry box.’

b. Low attachment

\[ \text{Gojuudai dansei-to suiteisareru] hannin no simon o 50s male-as supposed criminal gen fingerprint acc keisatu-ga nantoka mitukedasita.} \]

The police somehow found the fingerprint of the criminal who is supposed to be a male in his 50s.’

The high attachment sentence was read more slowly at the low noun ‘criminal’, the genitive marker and the high noun ‘fingerprint’ in (13a), but it was faster at sentence end (Kamide and Mitchell 1997, Experiment 2). Three types of explanations have been suggested for this reversal in reading times. The genitive marker no was shown separate from the noun ‘criminal’ in the self-paced reading presentation, delaying the realization that another noun is upcoming, thus possibly giving an artificial advantage to the low noun interpretation (Kamide et al. 1998). However, even when the two nouns and markers are shown in one single region (\textit{hannin-no simon-o}), there is still an initial preference for the low noun interpretation (Miyamoto, Nakamura and Takahashi 2004).

A second possibility is that readers are non-deterministically considering different interpretations at different points in the sentence (Kamide and Mitchell 1997), but recent evidence suggests otherwise as the same interpretation is maintained throughout (Aoyama and Inoue 2005). A third explanation is that the relative clauses are initially interpreted as matrix clauses and the reanalysis process to turn them into relative clauses favors the low noun as the attachment site. When canonical versions of (13a,b) are used making the embedded clause reading available before the head nouns, the initial advantage for low attachment disappears (Miyamoto, Nakamura
and Takahashi 2004).

Other factors have also been investigated by varying the types (e.g., inalienables, Uetsuki and Tokimoto 2004) and number of head nouns (Miyamoto et al. 1999) involved.

10 Scrambling

Some initial studies did not detect behavioral differences between scrambled orders and their canonical versions, and have been used to support non-configurational models of Japanese syntax or a trace-less representation for scrambled orders (Yamashita 1997; also Section 12 for discussions of Nakayama 1995, Sakamoto 2002). Although mounting evidence suggests that scrambled orders are harder to understand (apart from the studies discussed in the following sections, see Hagiwara and Caplan 1990, for data from aphasic patients, also Koizumi 2005, for an fMRI study), results have been inconsistent, and difficulty has been detected primarily with complex constructions.

10.1 Reading times to scrambled orders

Self-paced reading studies did not find statistically reliable differences between scrambled and canonical orders when using ditransitive verbs (Yamashita 1997) or transitives (Miyamoto and Takahashi 2002b, Nakayama 1995, also Section 12 for the probe recognition results of these experiments). Similarly, a center-screen self-paced reading experiment did not detect differences between the transitive sentences below (Mazuka, Itoh and Kondo 2002; the coindexed gap indicates the canonical position of the scrambled constituent.)

(14) a. Canonical order

Mariko-ga otooto-o yonda.
Mariko-nom brother-acc called

b. Scrambled order

Otooto-o, Mariko-ga gap, yonda.
brother-acc Mariko-nom called
‘Mariko called her brother.’

However, in an eye-tracking experiment, ‘Mariko-nom’ in the scrambled (14b) was read more slowly than ‘brother-acc’ in the canonical (14a) according to total reading times and regressive eye-movements, but not in more fine-grained measures such as first-pass fixations (Mazuka, Itoh and Kondo 2002, see Kondo, Mazuka and Kakehi 2002, for similar eye-tracking results and an interaction between lexical familiarity and word order, also Mazuka, Itoh and Kondo 2001, for ERP data).

In the same studies, Mazuka and colleagues also included sentences like the following in which the second argument is modified by a prenominal relative clause.

(15) a. Canonical order


Mariko-nom outside swing-dat riding brother-acc called

‘Mariko called her brother who was riding on a swing outside.’

b. Scrambled order


Mariko-acc outside swing-dat riding brother-nom called

‘The brother who was riding on a swing outside called Mariko.’

The canonical sentence is initially misanalyzed as ‘Mariko was riding the swing outside’ and a subject reanalysis is necessary at the head noun (Section 5); nevertheless, ‘brother’ is read more quickly in the canonical sentence than in the scrambled sentence. The difficulty at ‘brother-nom’ in (15b) was detected in self-paced reading as well as in first pass gaze time, total gaze time and number of regressive eye-movements in eye-tracking (Mazuka, Itoh and Kondo 2002).
Longer reading times were also detected in self-paced reading with ditransitive clauses followed by two other clauses in a left-branching configuration (Miyamoto and Takahashi 2002a, Experiment 1). The inclusion of the extra clauses may have forced participants to read carefully in order to answer the comprehension question that followed each item.

10.2 Plausibility judgements and word order

A plausibility task, in which the time to decide if a sentence makes sense is measured, has been successfully used with simple constructions without including artificially long phrases. For transitive constructions (such as (14)), it took longer to decide that the sentence made sense when the order was scrambled (Chujo 1983). Recently, various constructions have been investigated (Koizumi 2005, for a summary). For example, reaction times are faster for the ga-ni-o order than the ga-o-ni order for ditransitive verbs (Koizumi and Tamaoka 2004). The ga-ni order elicits faster reaction times for passives, but the ni-ga order is faster for potentials (Tamaoka et al. 2005, who also investigated causatives). But because the whole sentence is shown at once, the plausibility task is not very informative and it is unclear whether it can be used to disentangle the various sources of difficulty in scrambling (Miyamoto and Nakamura in press, for discussion) or to make claims about non-incrementality (as in Tamaoka et al. 2005).

10.3 Sources of difficulty in scrambling

A number of factors may be involved in the longer reading times for scrambled sentences compared to their canonical versions as the ones in (14) (Miyamoto and Takahashi 2002a, for discussion). At the sentence-initial direct object, the subject may be assumed to have been dropped, thus some time may be necessary to create a null subject. Then, when the nominative subject is detected, reanalysis will be necessary to remove the null subject.

A second factor is frequency. For example, an accusative object is rarely followed by a nominative NP (see Section 10.5). Thus, there is the possibility that long reading times occur at the nominative NP because it is rarely expected in such a configuration.
Another factor is the *adjacency constraint* — the preference for direct objects to be next to the verb. After a scrambled accusative NP, a constituent other than the expected verb is likely to be disruptive. ERP data indicate that immediately after a scrambled NP-o, a demonstrative (the first word of a NP-ga) elicits a P600 (Ueno and Kluender 2003), suggesting difficulty in integrating this word into the syntactic representation.

10.4 Filler-gap dependencies in scrambling

In an ERP study, a long subject following a scrambled direct object elicited a sustained anterior negativity before the verb was seen (Ueno and Kluender 2003), a response usually associated with extra memory load. This may have been caused by the processing of a filler-gap dependency as the scrambled constituent is identified as a filler which requires a gap in a manner similar to fronted wh-phrases (Section 8). The results of a self-paced reading experiment using sentences like the following (from Miyamoto and Takahashi 2004) support this interpretation.

(16) a. Ueitoresu-wa doogu-ga okareteiru sooko-de kokku-o,  
  waitress-top tools-nom stored room-loc cook-acc  
  rejigakari-ni gap<sub>i</sub> shookaisita sooda.  
  cashier-dat introduced seems

b. Ueitoresu-wa kokku-o, doogu-ga okareteiru sooko-de  
  waitress-top cook-acc tools-nom stored room-loc  
  rejigakari-ni gap<sub>i</sub> shookaisita sooda.  
  cashier-dat introduced seems

‘The waitress seems to have introduced the cook to the cashier in the room where the tools are stored.’

In (16a,b), ‘cook-acc’ was scrambled and a gap is necessary after the dative NP. Because the distance between filler and gap is greater in (16b), it should be harder to create the gap in
this sentence (Gibson 1998, on the effects of dependency length). This was in fact the case as the reading times for ‘cashier-dat’ were longer in (16b) than in (16a), while no differences were found between similar sentences with the direct object in canonical position (Miyamoto and Takahashi 2004). (The assumption is that the gap is created at the dative NP, before the verb is seen; Aoshima, Phillips and Weinberg 2004, for evidence). Furthermore, corpus counts suggest that these reading time patterns cannot be explained by the frequency of these constructions in newspapers (Miyamoto and Takahashi 2002a).

It is possible that for simple sentences (as in (14)), the cost of the filler-gap dependency is too small to be detected in self-paced reading, although it is picked up in eye-tracking. With long dependencies, the cost may be large enough to be seen in self-paced reading as well. In ERP, length seems to matter as well given that long NPs with transitive verbs lead to differences at the NPs themselves (Ueno and Kluender 2003), whereas short NPs in ditransitive constructions only lead to reliable differences at the predicate (Koso, Hagiwara and Soshi, 2005).

The filler-gap model is also supported by a self-paced reading result with scrambled wh-phrases in which a filled-gap effect (see Section 8) was detected (Aoshima, Phillips and Weinberg 2004; also Section 12 for reactivation effects at the gap position).

10.5 Frequency of scrambled orders

Scrambled orders are commonly claimed to be infrequent, but there are few reports with exact figures. The subject-object-verb (SOV) order has been claimed to be 17 times as frequent as the OSV order (Kuno 1973, p. 353-354). In a survey of 2,635 sentences from various sources, less than 1% included scrambled constituents (Yamashita 2002).

Corpus counts and completion data indicate that a sentence-initial object NP is rarely in a scrambling configuration preceding an overt subject. Out of 4,621 sentence-initial accusative NPs in the Kyoto University Corpus (Kurohashi and Nagao 1997), less than 2% were followed by an overt subject; in the remaining 98% of the cases, the subject was left implicit (Miyamoto
and Nakamura in press). Similarly, when asked to write a sentence starting with a NP-o, native speakers of Japanese dropped the subject in 210 instances (84.3%), and included a subject in 39 instances (15.7%). For NP-ni, 47 completions (19.8%) were followed by an overt subject (Miyamoto and Nakamura in press).

In the same completion study, oftentimes a NP-o was immediately followed by a predicate (64.7%) but rarely by a NP-ni (2%). In contrast, a NP-ni was equally likely to be followed by a predicate (36.7%) or a NP-o (33.3%; Miyamoto and Nakamura in press). In other words, the canonical ni-o order is frequent, but the scrambled o-ni is rare.

11 Production

A survey of sentence production is beyond the scope of this chapter; however, two studies will be discussed as examples of how production may affect the frequency with which people are exposed to different constructions. Whether frequency-based accounts can explain comprehension difficulty remains an open question, and they may seem unsatisfactory conceptually. If a construction is easy to understand because it is frequently seen, that begs the question as to why the construction is frequently used in the first place. One possibility is that production factors determine the frequency with which syntactic constructions are used. Two factors often claimed to affect the production of scrambled constituents are NP length and information status in discourse.

With short NPs, fewer than 5% of utterances produced are scrambled (OSV). However, when the object is long, that number rises to 20% (Yamashita and Chang 2001). One possible explanation is that speakers prefer to front the long object in order to keep the argument heads close to the predicate thus shortening the dependencies.

However, another study did not find effects of information status on scrambling. After hearing ditransitive constructions, speakers were more likely to reverse the order of the two objects when the original order was scrambled (thus, recalling ni-o after hearing o-ni 67.2% of
the time) than when the original order was canonical (29.2%). There was also a preference to recall given information before new information, but information status did not interact with word order, as the advantage for the given-new order was the same for both orders (20.2 % for ni-o and 20.3% for o-ni, Ferreira and Yoshita 2003, Figure 3), this suggests that scrambling in Japanese is not used to indicate information status in discourse.

12  Antecedent resolution for pronouns and gaps

Work in English indicates that the antecedent of pronouns and gaps is reactivated when those elements are processed during sentence comprehension (Bever and McElree 1988, and references therein). Immediately after reading sentences like the following, participants are shown a probe word and have to decide whether it appeared in the sentence.

(17) a. [The astute lawyer who faced the female judge] was suspected gap, constantly.

b. The astute lawyer who faced the female judge was suspicious constantly.

Participants are faster to recognize the probe astute in the passive condition (17a) than in the adjective condition (17b). The assumption is that the gap in the passive condition has to access its antecedent, refreshing its representation and facilitating recognition.

12.1 Antecedent reactivation in scrambling

Reactivation observed in unaccusative constructions (compared to unergatives) indicates that reactivation at gaps occurs in Japanese as well (Nakayama 1991, briefly reported in Nakayama 1995). Hence, if scrambled constituents involve filler-gap dependencies, facilitation should be observed for (18a) compared to (18b) (Nakayama 1995).

(18) a. Scrambling condition

[Shukudai-o wasureta seito-o], mondai-o dasita sensei-ga gap, sikatta.

homework-acc forgot student-acc question-acc posed teacher-nom scolded

‘The teacher who posed the question scolded the student who forgot the homework.’
b. Canonical condition

Mondai-o dasita sensei-ga shukudai-o wasureta seito-o sikatta.

question-acc posed teacher-nom homework-acc forgot student-acc scolded

‘The teacher who posed the question scolded the student who forgot the homework.’

Contrary to the filler-gap predictions, ‘homework’ was recognized faster after the canonical (18b). But note that ‘homework’ is closer to the sentence end in (18b), thus potentially facilitating recognition (also (18b) requires a subject reanalysis, Section 5.1, see Miyamoto and Takahashi 2002b, for discussion). When the probe is in the same linear position, either no difference is detected (Nakayama 1995, Experiment 2) or the probe in the scrambled NP is recognized faster as predicted by the filler-gap model (Miyamoto and Takahashi 2002b, see Nakano, Felser and Clahsen 2002, for cross-modal priming with long-distance scrambling).

12.2 Antecedent reactivation with jibun

In (19), the antecedent for the reflexive pronoun jibun can be either the subject ‘Taro-top’ or the agent of the passive ‘Hanako-dat’.

(19) Taro-wa Hanako-ni jibun-no kazoku-no hanasi bakari sareta.

Taro-top Hanako-dat self-gen family-gen talk only was

‘Taro was told by Hanako nothing but stories about his/her own family.’

During the 1-second per bunsetsu RSVP, a probe was shown surrounded by angle brackets and participants had to decide whether it had appeared previously in the sentence. Reaction times were faster for subject probes than passive-agent probes immediately after jibun as well as at sentence end (Nagata 1991, Experiment 1, see Experiment 2, for similar results when the order of the first two NPs is swapped, although the difference is not reliable immediately after jibun, also Nagata 1992, for evidence that there is no subject advantage in sentences without jibun). With contexts favoring the passive-agent reading, no difference was detected at
sentence-end, although the subject advantage remained immediately after *jibun* (Nagata 1991, Experiment 3). When causatives are used as in (20), only the dative NP can be the antecedent; nevertheless, subject probes were recognized faster immediately after *jibun* as well as at sentence end.

(20) Simizusan-wa Katosan-ni jibun-no sigoto-o tanosimaset.

Simizu-top Kato-dat self-gen work-acc enjoy-made
‘Simizu made Kato, enjoy self’s work.’

One possibility is that the verb morphology has a late effect. Alternatively, it is conceivable that the causative did not have the effect intended and participants maintained the subject interpretation throughout.

12.3 Antecedent resolution in control constructions

After hearing a sentence with a subject and an object in the matrix clause, Japanese speakers were faster to recognize the antecedent for PRO in the embedded clause if the matrix predicate was a *subject-control verb* rather than an *object-control verb* (Sakamoto 2002, Experiment 1, also Experiment 2 for the same outcome when the object is scrambled prior to the subject). Because the stimuli were created by splicing words pronounced individually, the experiment was replicated using sentences spoken with normal prosody. The task was also modified so that participants had to say aloud the antecedent for PRO. With this setup, reaction times for object-control verbs were faster (Sakamoto 2002, Experiments 3, also Experiment 4 for the same result when the object was scrambled). Moreover, for all sentences, the embedded clause was ‘go to Tokyo’ and participants were instructed to determine which person in the sentence had gone to Tokyo, potentially allowing the use of task-specific strategies (Sakamoto 2002, and references therein, for other factors that may have led to the diverging results and the theoretical issues that such experiments have the potential to address).
13 Center-embedding and multiple nominative NPs

Center-embedding constructions, in which clauses are nested within one another, are known to be difficult to understand compared to sentences with the same clauses arranged in right-branching or left-branching structures (Miller and Chomsky 1963). Sentence (21) is probably unprocessable for most speakers (from Uehara and Bradley 2002; also Mazuka et al. 1989, for whole-sentence reading times to center-embedding and left-branching sentences; Section 5 for a discussion of Inui et al. 1998, who reported an fMRI study comparing center-embedding and left-branching sentences).

(21) Sensei-ga gakusei-ga onnanoko-ga shoonen-o mikaketa-to hanasita-to itta.

   teacher-nom student-nom girl-nom boy-acc saw-that told-that said

   ‘The teacher said that the student told that the girl saw the boy.’

Ambiguity in nominative NPs (they usually mark subjects but can mark the object of stative predicates) is unlikely to be the source of the difficulty. When asked to write sentences starting with an animate nominative NP, Japanese speakers virtually always (98% of the time) use the nominative NP as the subject of the sentence (Nakamura and Miyamoto 2007). Moreover, since the topic marker *wa* is even more ambiguous (it is preferentially interpreted as a subject in 78% of sentence completions, Nakamura and Miyamoto 2007), it should make the sentence harder to understand if the issue was ambiguity. However, the sentence becomes easier when the first nominative marker is replaced by the topic marker (Babyonyshev and Gibson 1999, Experiment 1, and Uehara and Bradley 2002, Experiment 1, for questionnaire studies, and Miyamoto 2002, for self-paced reading data).

Moreover, according to completion data (Uehara and Bradley 2002, Experiment 3), each nominative NP tends to be interpreted as part of a separate clause. Speakers do not interpret a NP-ga as the object of a stative verb, even though that would decrease the number of predicates (and of embedding levels) necessary to complete the sentence.
The difficulty in processing multiple nominative NPs can be explained in terms of the load that such sequences impose as they require the prediction of several syntactic heads to complete the sentence (Section 8; also Babyonyshev and Gibson 1999, Nakatani and Gibson 2003, for comparisons of different types of embeddings and the predictions of various versions of memory-load models of processing). However, this still fails to explain why topicalization facilitates comprehension. The proposal that the same case marker used in succession leads to phonological interference (Lewis and Nakayama 2002) is supported by data in Korean, according to which a sequence of nominative NPs is easier to process when they are phonologically distinct (Lee and Nakayama 2003, but see Uehara and Bradley 2002, Experiment 2).

14 In-situ wh-phrases

In-situ wh-phrases do not require a gap, thus they lack the feature that has attracted most attention in fronted wh-phrases. However, they require a question particle (Nakagome et al. 2001, for a P600 response to the declarative particle yo following a wh-phrase). In (22), ‘what kind of computer-acc’ is in-situ and is licensed by the question particle no.

(22) Senmu-ga donna-pasokon-o tukatteiru-to kakarichoo-ga itta-no?

   director-nom what-kind-computer-acc using-is-that supervisor-nom said-qp

   ‘What kind of computer did the supervisor say the director is using?’

Self-paced reading experiments indicate that in-situ wh-phrases trigger the search for a question particle in a manner similar to gap searching for wh-phrases in English. Readers slow down at the embedded verb with the declarative complementizer to ‘that’ in (22) in comparison to a similar sentence containing the question particle ka after the embedded verb. In this typing mismatch effect, the expectation for a question particle at the earliest point allowed by the grammar is violated by a constituent with declarative typing (Miyamoto and Takahashi 2002c). This effect has been claimed to be the in-situ equivalent of the filled-gap effect (Section 8) and it has been shown to obey grammatical constraints and to be observable even when the initial segment
of the sentence indicates that another possible position for the question particle is upcoming in
the sentence (Miyamoto and Takahashi 2002d, Experiments 2 and 3). The typing mismatch
effect has also been detected for scrambled dative wh-phrases (Aoshima, Phillips and Weinberg
2004), negative polarity items (Yoshida 2004) and exclamatives (Ono et al. 2006).

Wh-phrases are an example of how the same processing strategy can surface in different
guises in different languages. To be interpreted, wh-phrases require their scope and thematic
role to be determined. English indicates the scope position by pronouncing the wh-phrase at the
relevant clausal level, and the thematic-role requirement is satisfied by searching for a gap. In
Japanese, in contrast, wh-phrases are pronounced at the thematic position, and scope requires
searching for a question particle. In short, the constituent sought (a gap or a question particle)
is determined by the grammar of each language, but the search process is similar as expected if
a single processing algorithm is used for all human languages.

15 Implications for the general theory

An implicit assumption throughout this chapter was that grammatical knowledge guides pro-
cessing by providing alternative interpretations, from which factors such as cognitive resources
and plausibility choose (e.g., after a wh-phrase, the grammar of Japanese indicates the positions
where a question particle can occur, but it is memory cost that eventually favors the earliest
one among them). However, alternative views for the role of the grammar have been proposed.
In the competition model, the grammar is not as crucial and can be overridden if enough cues
supporting an ungrammatical interpretation are available (Sasaki and MacWhinney in press,
for results on Japanese within this framework). It remains to be seen whether the competition
model is able to cover constructions more complex than the single-clause structures usually
examined.

There are also approaches in which the grammar takes an even more critical role than as-
sumed here, as syntactic complexity is claimed to determine processing difficulty. Those in-
clude recent proposals linking the difficulty in scrambled orders with the complexity of their syntactic representation (Koizumi 2005, Koizumi and Tamaoka 2004) and proposals based on the height of the syntactic structure (Hagiwara in press, for a summary of how the number of merge operations counted from the bottom up in the structure explains data from aphasic patients and ERP studies). Since the 1970’s it has been known that a large portion of processing difficulty lies in extracting the meaning intended from superficial cues in the sentence (Fodor, Bever and Garrett 1974). Hence, the challenge for competence-based models of performance is to describe how their metrics affect processing on-line, as each word is read, and then support their predictions with evidence that cannot be explained by independent factors (e.g., plausibility, frequency, ambiguity) that are likely to affect parsing.

Clearly, whichever the approach adopted, many issues still need to be addressed in the mapping between grammar and its use in parsing, and their resolution are likely to affect our understanding of performance as well as competence-related issues in language.

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