Factors in the incremental processing of NPs in Japanese

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1. Introduction

How do people understand the meaning conveyed by sentences? What happens as each word in the sentence is read (or heard)? How much of the meaning intended can be understood before the end of the sentence is reached? How much crosslinguistic variation is there? These are some of the questions addressed in the field of sentence processing.

In English, processing is incremental in that native speakers interpret each incoming word in relation to the previous ones without waiting for the rest of the sentence (Marslen-Wilson, 1975). So after reading the fragment Mary gave, the noun is interpreted as the subject of the verb even if it is not clear yet what the objects are going to be. Interpretation proceeds with the expectation that the necessary constituents (i.e., a direct object and an indirect object) will follow. That processing is incremental is uncontroversial for constructions in which the verb comes early in the clause (e.g., SVO constructions in Romance languages, matrix clauses in Dutch and German). The status of verb final constructions has been far more controversial, but extensive evidence is now available that the processing of SOV sequences is incremental. The bulk of the evidence has come from Japanese.

The problem with verb final clauses is that whenever two or more NPs (or PPs) are encountered it is not entirely clear how incremental processing should proceed since one NP cannot take the other as an argument (in the way that the verb gave can take Mary as its subject).

It has been suggested that the head of a phrase is crucial and processing
cannot proceed without it (Pritchett, 1991). For example, a VP node cannot be projected until the verb is read in a re-interpretation of the Projection Principle (Chomsky, 1981) for processing purposes. As a consequence, the arguments and adjuncts of a verb in head final languages cannot be associated to each other until the verb is seen. Pritchett’s proposal is an elegant attempt to reduce processing mechanisms to a strict implementation of grammatical principles, however the vast majority of empirical studies have challenged its predictions (but see O’Grady, Nakamura & Lee, 2002).

2. Case markers

Starting with detailed discussions in Inoue (1991) based on intuitive judgments (also Inoue & Fodor, 1995), various studies indicate that native Japanese speakers associate NPs together with the expectation that the appropriate verb will come eventually. So, when the sequence ‘Mary-nom John-dat flowers-acc’ is read in Japanese, there is the expectation that a ditransitive verb will follow taking the first NP as its subject and the last two as objects (Yamashita, 2000; also Scheepers, et al., 1999, for a related discussion on German). Thus, even if the exact verb is not known, it is possible to create the interpretation that ‘Mary is acting on the flowers for (the benefit of) John’ based on information such as case markers. One possible implementation of such a procedure is to assume that the non-terminal nodes (VP, TP and so forth) are projected based on underspecified head nodes (e.g., a verb whose exact lexical entry is not known, but that satisfies the constraints imposed by the case-marked NPs read thus far by, for example, having an appropriate argument structure).

Reliance on case marking for incremental processing has been challenged on the basis that case markers do not have a one-to-one correspondence with thematic roles (Pritchett, 1991). However, ambiguity does not prevent the use of other types of information during parsing. For example, in English, verbs such as confirm are ambiguous and allow two types of complements (a direct object as in confirmed
the rumor or a sentential complement as in confirmed the rumor should have been stopped sooner), however that does not preclude English speakers from using the most frequent argument structure of this verb in order to process sentences (Garnsey, Pearlmutter, Myers & Lotocky, 1997). Similarly, it is possible that Japanese speakers adopt the thematic role that is most often used with a given case marker and the noun it is attached to.

One may still be left with the impression that processing in head-initial languages is far less ambiguous given that the thematic role of, for example, a subject is immediately assigned by the verb, whereas in head final languages like Japanese only vague roles are determined before the verb is seen. But in fact the difference is not as stark as it may seem. Note that the precise thematic role of a subject is not always known when the verb is read because it is the compound of verb and direct object that assigns the thematic role to the subject (Marantz, 1984). For example, in the fragment Ken threw, the exact thematic role of Ken cannot be determined until the object is read (i.e., the role of Ken will depend on whether he threw a ball, a party, a tantrum, the towel), thus uncertainty in thematic roles is not the dubious privilege of head final languages but it commonly occurs in the processing of any language.

2.1 Boundary between clauses

Whenever possible, readers assume that a sequence of NPs will be attached to a single predicate (e.g., Inoue, 1991; Mazuka & Itoh, 1995; Yamashita, 2000). However, in some sequences case markers make clear that a single predicate is not going to suffice. For example, when a sequence contains two accusative NPs, it is clear that at least two predicates will follow in order to complete the sentence because two accusative NPs cannot be part of the same clause (Harada, 1973, and references therein) and readers are able to use this kind of information in order to structure the input string into clauses before any predicate is seen (Miyamoto, 2002).
Moreover, each nominative NP tends to be interpreted as part of a different clause (Miyamoto, 2002; Uehara & Bradley, 2002; also Garnsey, Yamashita, Itoh & McClure 2001, for ERP data) as each one is preferentially associated with a different predicate. Note that in Japanese there are no markers that indicate the initial boundary of an embedded clause, and nominative NPs may be the clearest indicators for the beginning of a new clause given their syntactic properties (e.g., they cannot be scrambled, Saito, 1985; they have to be associated with an inflected predicate, Takezawa, 1987).

Apart from case markers, there is also evidence indicating that animacy is a factor that influences the processing of NPs and the expectations for the types of predicates that will follow (Den & Inoue, 1997; Muraoka & Sakamoto, 2004). For example, in the sequence NP-dat NP-nom NP-nom it is clear that at least two predicates are necessary to complete the sentence (given that no single predicate in Japanese can be associated with those three NPs), and animacy of the second nominative NP affects its reading times (Muraoka & Sakamoto, 2004).

2.2 Processing within clauses

Empirical results confirm the incremental nature of processing in sentences with single clauses as well. For example, antecedent assignment for pronouns is conducted according to detailed syntactic constraints before the verb is seen (Aoshima, Phillips & Weinberg, 2003).

Moreover, studies investigating word order differences indicate that NPs in canonical order (e.g., NP-nom NP-acc) are read faster than in scrambled order (NP-acc NP-nom; Mazuka, Itoh & Kondo, 2002; Miyamoto & Takahashi, 2002, 2004; also, Ueno & Kluender, 2003, for ERP data; Nakano, Felser, & Clahsen, 2002, for antecedent reactivation; and Miyamoto, 2006, for a summary). Because the differences are detected before the verb is read, these results indicate that readers are not simply storing the NPs waiting for the verb, but rather some type of relation between the NPs is being established.
Furthermore, in a study using the visual world paradigm, in which eye movements over actual objects or pictures are monitored, Japanese speakers heard fragments like the ones in (1a, b) while they looked at a picture containing a waitress, a customer, a hamburger and a distractor item (a trash can).

(1) a. Ueitoresu-ga kyaku-ni tanosigeni
    waitress-nom customer-dat cheerfully

b. Ueitoresu-ga kyaku-o tanosigeni
    waitress-nom customer-acc cheerfully

By the time ‘cheerfully’ was heard, there were more predictive eye movements towards the hamburger while hearing (1a) than (1b) (Kamide, Altmann & Haywood, 2003). This suggests that the case marker on the second NP in the fragments influences the expectations that hearers have as to how the sentence will continue. One way of understanding the result is to suggest that the NPs ‘waitress-nom’ and ‘customer-acc’ are associated together as part of a single event (e.g., the waitress brought something to the customer) and a direct object such as ‘hamburger’ would be a natural continuation. Alternatively, it is also possible to assume that the NPs are not interpreted together and it is the dative marker in (1a) that creates the expectation for another NP. In other words, although some semantic interpretation may be going on, it is unclear how detailed it is. What is clear, however, is that the case markers are having a crucial role in the process as the dative NP is increasing the likelihood that another NP will follow.

That dative NPs lead to different expectations compared to accusative NPs is confirmed by a completion questionnaire in which participants were provided with an animate case-marked NP and asked to write a sentence starting with it (Miyamoto & Nakamura, 2005). When the NP was marked with the dative marker, it was immediately followed by an accusative NP in 33.3% of the completions, and by a verb in 36.7%. In contrast, an accusative NP was immediately
followed by a verb in 64.7% of the completions and it was rarely followed by another NP (2.4%).

3. Frequency of multiple preverbal constituents

The question of whether NPs are interpreted together before the verb is seen is crucial because it can determine the memory load involved in the processing of sentences in verb-final clauses. For example, it is much more difficult to remember the sequence of 10 digits 7 0 1 9 4 5 2 0 1 5 than the sequence of 3 numbers 70-1945-2015 or the fact that it will be 70 years since the end of World War II in the year 2015 (see Miller, 1963, on chunking). The same difficulty should occur if constituents were not interpreted together in head-final constructions and readers were forced to store each one of them in isolation in working memory. This should lead to a considerable disadvantage in comparison to languages in which the verb comes early in the clause. Considering the pressure that such a working memory load would exert on language acquisition and language change, one should predict that SOV languages should be far less common than SVO languages, contrary to what has been reported in some estimates (Dryer, 1989).

There is, however, another factor that may need to be taken into consideration, namely that languages like Japanese allow constituents to be left implicit. Thus, it is possible that such strategies of leaving constituents implicit would ameliorate the effects of working memory load. If this is correct, sequences of multiple pre-verbal constituents should be rare. This possibility was investigated in a corpus count. A total of 38,383 sentences from the Mainichi Shinbun (Kyoto Corpus; Kurohashi & Nagao, 1997) were checked in order to determine the number of pre-verbal constituents (arguments and adjuncts) and their frequency. Results are reported in Table 1. The first column indicates the number of constituents that preceded the head. Results are classified according to the type of head (verbs, verbal nouns and others). For example, there were 19,874 occurrences of two constituents preceding a verb.
As expected, frequency decreases rapidly beyond three constituents. However, in the first column alone, there are more than 1,000 occurrences of five or more pre-verbal constituents. This is a sizable number if one considers that about 38,000 sentences were checked. Thus, in average, for every 38 sentences there is roughly one occurrence of a verb preceded by five or more constituents.

The generality of the results is clearly limited by the newspaper origin of the sentences; nevertheless, they suggest that the processing of multiple pre-verbal constituents is not a rarefied theoretical issue, but rather readers are likely to be often confronted with sequences of multiple constituents before seeing the subcategorizing verb.

### 4. Possessor relations

If sequences of constituents are commonly encountered as argued in the previous section, the question is how they are interpreted. Consider the following example.
Given the results surveyed earlier, it seems reasonable to assume that a syntactic representation including all four constituents is built, but the question then is how much semantic interpretation takes place before the verb is seen. The question becomes more interesting considering that native speakers are in average able to read such a sequence in about a second. How much are readers able to accomplish in such a short period of time? When they read ‘email-acc’ are they able to infer that ‘Ken’ acted on an ‘email’ (e.g., read/received/sent/wrote)? When ‘brother’ is read next, do readers assume that it is Ken’s brother that is being referred to? Or is it more likely that it will be assumed that it is the speaker’s brother given that the more informal *otouto* was used rather than the more polite form *otouto-san* used to refer to somebody else’s brother?

There are two types of incremental explanations that one can entertain. Both are incremental as they assume that the syntactic representation is built without delay. But they differ in the way semantic interpretation takes place. In the first model, thematic roles are assigned based exclusively on local information such as case markers and animacy. In the second model, on top of information local to each NP, possible relations to previous NPs are also taken into consideration; so, for example, possessor-possessee relations may affect the interpretation process.

In three fragment completion questionnaires, Yoko Iguchi (from Kobe Shoin Women’s University) and I investigated the influence of such possessor relations (Iguchi & Miyamoto, 2006). We compared *saturated* NPs (entities that in general do not presuppose an owner; e.g., professions such as *pianisuto* ‘pianist’) to *unsaturated* NPs (entities that usually belong to somebody; e.g., inalienables such as body parts and kinship terms).

This takes advantage of the fact that in Japanese the owner of unsaturated nouns is often left implicit, and it can be represented with a phonologically-null
pronoun. So what in English is expressed as (3a) would be expressed as (3b), and the possessor (indicated with pro) has to be determined from the context.

(3) a. his brother
   b. pro otoutu
      brother

   The question, then, is whether the pro in this case would trigger the search for an antecedent, thus creating a possessor-possessee relation with a previous NP and potentially affecting the interpretation process in ways not observed with saturated entities.

4.1 Experiment 1

In Experiment 1, fragments containing two nominative NPs like the following were used.

(4) a. Unsaturated / Animate
   Akira-kun-ga hahaoya-ga
   Akira-title-nom mother-nom
b. Unsaturated / Inanimate
   Akira-kun-ga mokuhyou-ga
   Akira-title-nom goal-nom
c. Saturated / Animate
   Yoko-chan-ga ano pianisuto-ga
   Yoko-title-nom that pianist-nom
d. Saturated / Inanimate
   Yoko-chan-ga konyano hoshizora-ga
   Yoko-title-nom tonight starlit sky-nom
The first nominative NP in each fragment was always a human proper name. The second NP varied according to animacy and saturation.

A total of 768 sentence completion responses (24 fragments × 32 participants) were obtained, of which 17 (2.21%) were not included in further analyses as they were ambiguous, incomplete or ungrammatical. For the remaining, there were fewer completions (45 cases) in which the two nominative NPs belonged to the same clause than to different clauses (706 cases) confirming previous results according to which readers prefer to interpret each nominative NP as part of a separate clause (Miyamoto, 2002; Uehara & Bradley, 2002).

The effects of animacy and saturation were evaluated by counting the number of same-clause completions in each condition. This is a straightforward way of determining the influence of those factors given that the roles of the NPs are likely to be different depending on the number of clauses involved. Fisher probability exact tests (FPET) were conducted (differences are reported as statistically reliable when $P < 0.05$, and as not reliable when $P > 0.1$).

The animacy effect depended on saturation as the proportion of same-clause to different-clause completions was larger in the Unsaturated/Inanimate condition (24/68) than in the Unsaturated/Animate condition (3/93) while the Saturated/Inanimate condition (3/92) and the Saturated/Animate condition (7/89) did not differ. In other words, animacy is modulated by the possible relations between NPs, and in the present case it only has an effect on clause boundary insertion when the second nominative NP is unsaturated.

4.2 Experiment 2

Because the nouns used in Experiment 1 were different in a number of ways and not just in terms of saturation (e.g., ‘goal’ compared to ‘tonight’s starlit sky’; ‘mother’ compared to ‘pianist’), another experiment was conducted in which the head noun was kept constant across conditions as shown in the following example set.
(5) a. NP-ga NP-ga (Unsaturated / Animate)
   Akira-kun-ga  hahaoya-ga
   Akira-title-nom mother-nom

b. NP-ga NP-ga (Unsaturated / Inanimate)
   Akira-kun-ga  mokuhyou-ga
   Akira-title-nom goal-nom

c. NP-ga NP-no NP-ga (Saturated / Animate)
   Akira-kun-ga  Yumi-chan-no  hahaoya-ga
   Akira-title-nom Yumi-title-Gen mother-nom

d. NP-ga NP-no NP-ga (Saturated / Inanimate)
   Akira-kun-ga  Yumi-chan-no  mokuhyou-ga
   Akira-title-nom Yumi-title-Gen goal-nom

Saturation in this case is determined based on whether a possessor phrase (Yumi-chan-no) was included or not. With this phrase present, the second nominative NP becomes saturated as its possessor becomes explicit, thus blocking a possible possessor relation with the first nominative NP.

Out of 480 completion responses obtained (20 fragments × 24 participants), there were 15 (3.125%) ungrammatical, incomplete or ambiguous, which were not included in further analyses. For the remaining, there were more completions in which the two nominative NPs belonged to different clauses (408 instances) than completions in which they were in the same clause (57 instance), replicating once more the preference that readers have for interpreting each nominative NP as part of a separate clause.

Similar to the first experiment, the effect of animacy was dependent on saturation as the proportion of same-clause to different-clause completions was larger for the Unsaturated/Inanimate (35/82) than for the Unsaturated/Animate condition (14/102), whereas for the two Saturated conditions, the proportion for the Inanimate (2/118) and the Animate conditions (6/106) did not differ.
4.3 Experiment 3

The acceptability of sequences with multiple nominative NPs varies across individuals, and some consider them ungrammatical. This is true both for nominative NPs that are in different clauses and for those in the same clause, but it is perhaps stronger in the latter case. The processing of a sequence with multiple nominative NPs is known to become easier if the first one is replaced with the topic marker *wa* (Babyonyshev & Gibson, 1999; Miyamoto, 2002; Uehara, 1997). It is conceivable that repetition of the same case marker is dispreferred because of phonological confusability in working memory (see Baddeley, 1992, on the phonological similarity effect and the articulatory loop), and data from Korean is compatible with this claim as a sequence of nominative NPs is easier to understand if the nominative markers used are phonologically distinct (Hagstrom & Rhee, 1997; Lee and Nakayama, 2003).

Whatever the reason for such a difficulty with multiple nominative NPs in Japanese, it should not interact with the findings of the first two experiments. Nevertheless, a third questionnaire was conducted by substituting the topic marker for the first nominative marker in the fragments of Experiment 2. Analyses of variance were conducted on the arcsine transformed number of same-clause completions using participant means ($F_1$) and item means ($F_2$).

There was a total of 480 completion responses (20 fragments × 24 participants), and five were ungrammatical, ambiguous or incomplete and were not included in further analyses. For the remaining 475, there were fewer completions in which the topic NP and the nominative NP belonged to the same clause (222 instances) than completions in which they were in different clauses (253 instances). The proportion of same clause to different clauses was clearly larger in this experiment (222/253) than in Experiment 2 (58/408; FPET: $P<0.0001$), suggesting that the nominative NP is more likely to be part of the same clause when the first NP has the topic marker (Experiment 3) rather than the nominative marker (Experiment 2).
In spite of this difference, the effects of saturation and animacy were consistent with the findings of the other two experiments. Most crucially, there was an interaction between animacy and saturation ($F_1(1,23) = 10.6$, $P < 0.01$; $F_2(1,19) = 10.17$, $P < 0.01$) as the Unsaturated/Inanimate condition (98) had more same-clause completions than the Unsaturated/Animate (49; $F_1(1,23) = 44.9$, $P < 0.001$; $F_2(1,19) = 33.7$, $P < 0.001$), whereas the Saturated/Inanimate condition (43) and the Saturated/Animate condition (32) did not differ ($F_1(1,23) = 2.77$, $P > 0.1$; $F_2(1,19) = 1.33$, $P > 0.26$).

There was also a main effect of saturation as the Saturated conditions led to fewer same-clause completions than the Unsaturated ones ($F_1(1,23) = 45.19$, $P < 0.001$; $F_2(1,19) = 49.81$, $P < 0.001$). The main effect of animacy was also reliable as the Inanimate conditions led to more same-clause completions than the Animate ones ($F_1(1,23) = 45.88$, $P < 0.001$; $F_2(1,19) = 20.94$, $P < 0.001$).

Although there were considerably more same clause completions in Experiment 3 than in Experiment 2, the claim that saturation has a critical effect on NP interpretation is once more observed. The interaction between saturation and animacy in particular is in line with the results of the first two experiments. This suggests that NPs are being interpreted together based on the possible relations that can hold between them and this affects the way how local information such as animacy is taken into account.

Previous results according to which a topic NP and a nominative NP are preferentially taken to be part of different clauses need to be interpreted with the qualification that they were obtained with saturated animate nouns. With unsaturated inanimate nouns, we see a reversal in preference with more same-clause completions (98 out of 119 completions).

Due to limitations inherent to the questionnaire methodology used, the experiments reported here can only support the claim that possessor-possessee relations influence the way how sequences of NPs are interpreted, however they do not make it clear how soon such information is used by readers. We are currently con-
sidering ways of conducting reading time experiments addressing such questions.

Another issue that needs consideration is that the saturated conditions were longer (in number of characters or in number of bunsetsus) than the unsaturated conditions in all three experiments. One could argue that longer NPs increases memory load, thus it is the length of the NPs and not saturation or animacy that affected clause boundary placement. One problem with this explanation is that extra memory load should steer readers away from complex multi-clausal interpretations, in which case, readers should avoid putting the two NPs in different clauses in the longer Saturated conditions, the opposite of what we observed in the experiments.

An alternative way in which length can affect clause boundary insertion is in terms of implicit prosodic contours that may be imposed on fragments read in silence (Fodor, 1998). It has been shown that when the initial NP of a fragment is longer, it is more likely for a pause to be inserted immediately after it, thence increasing the likelihood for an embedded clause boundary to be inserted (Hirose, 2003). However, in the experiments reported here the longer phrases occurred after the initial NP, therefore their effects on prosody should be different, but clearly they need to be further investigated.

In sum, possible effects of length differences need to be addressed in the future. Furthermore, we are also investigating ways of determining whether possessor relations are effected immediately as soon as the unsaturated NP is read or whether they are only computed with some delay. The timing with which saturation is used is important as it can determine to what extent two NPs are interpreted in relation to each other before the verb is seen. The possibility that such processing occurs only at the predicate needs to be addressed in reading time experiments.

5. Word order and frequency effects

Up to this point, the discussion has centered on how NPs can be related
to each other based on their case markers, animacy, saturation, but the relation between NPs is created assuming that an appropriate predicate will follow. For example, after three NPs with nominative, dative and accusative case, a ditransitive verb such as *dashita* ‘serve’ is expected (Yamashita, 2000). The question is whether information other than case marking can help readers predict the kind of verb that will eventually come at the end of the clause.

In English, there is evidence that the frequency of use of different argument structures affects the interpretation of an ambiguous postverbal NP. For example, in the fragment *the director confirmed the rumor*, the NP *the rumor* can be the direct object of *confirmed* (as in in (6a)) or the subject of an embedded clause (as in in (6b)).

(6) Direct-object biased verb (*confirm*)

a. The director confirmed the rumor during the interview.

b. The director confirmed the rumor should have been stopped sooner.

A similar ambiguity is observed for *the mistake* in relation to the verb *admitted* in (7a, b).

(7) Sentential-complement biased verb (*admit*)

a. The agent admitted the mistake during the interview.

b. The agent admitted the mistake had been careless.

Despite the similarity in their ambiguous argument structures, the postverbal NP is treated differently after *confirm* and after *admit*. Verbs such as *confirm* are more frequently seen with a direct-object and reading times indicate bias favoring this interpretation, whereas the opposite tendency is observed with verbs such as
admit that are more commonly followed by a sentential complement (Garnsey, Pearlmutter, Myers & Lotocky, 1997).

In order to investigate whether a similar effect is observed in Japanese, a study was conducted in collaboration with Fumi Ito, Asako Kajiwara and Yukari Tamura (from the University of Tsukuba). More precisely, the goal was to determine whether word-order frequency has any effect on the processing time at the verb (Miyamoto, Tamura, Kajiwara & Ito, 2005; also Miyamoto, in press, for a discussion). It is conceivable that after reading NPs in a certain order, readers are more likely to expect a given type of verb (but see Yamashita, 2000, who did not detect such an effect).

In a stop-making sense experiment, using a non-cumulative moving-window self-paced presentation, participants pressed a button to reveal each segment of the sentence one at a time, and pressed another button as soon as they thought the sentence did not make sense. Pairs of test items as in (8) and (9) were used.

(8) High frequency verb (yobu ‘call’)

a. Canonical order (NP-nom NP-acc)
Yonakano denwade byoukino shufu-ga kinjono isha-o
middle-night phone sick housewife-nom neighbor doctor-acc
yonda rasii.
called seems

b. Scrambled order (NP-acc NP-nom)
Yonakano denwade kinjono isha-o byoukino shufu-ga
middle-night phone neighbor doctor-acc sick housewife-nom
yonda rasii.
called seems

‘In a phone call in the middle of the night, the sick housewife called the local doctor.’
The only difference is whether the subject comes before the direct object in the more common order in (8a) and (9a), or after the direct object in the scrambled order in (8b) and (9b). Note that word order does not affect the propositional content of the sentences.

Apart from word order, the 2×2 design manipulated the frequency of the matrix verb. There were 12 pairs of sentences that used high-frequency verbs (with more than 1.2 million hits on the internet search engine Google, $M=3.185$ million hits; e.g., *yobu* ‘call’) and 12 pairs of sentences with low frequency verbs (fewer than 400,000 hits, $M=129,998$; e.g., *homeru* ‘praise’).

A total of 80 items (24 test items, 16 plausible fillers, and 40 fillers that became implausible at various points) were read by 32 native Japanese speakers. Implausible items were judged to be implausible (97.4%) more often than the plausible items (7.2%; $P<0.001$). For the test items, the low-frequency verb items were judged to be implausible (10.7%) more often that the ones with high-frequency verbs (7.6%) marginally in the participant analysis ($F_{1(1,31)}=3.72,$
There were no word order or interaction effects ($P_s > 0.14$).

### 5.1 Reading time results

Residual reading times compensating for differences in word length (Ferreira & Clifton, 1986) were analyzed with the following results at the matrix verb (‘called’ in (8a, b) and ‘praised’ in (9a, b); results in the other regions were compatible with previous studies and are discussed in Miyamoto, in press). The low-frequency verbs were read more slowly than the high-frequency verbs ($P_s < 0.05$); this is expected as less frequent words take longer to read (Ashby, Rayner & Clifton, 2005, for recent results and references). Moreover, the scrambled conditions were slower than the canonical conditions ($P_s < 0.005$); this result is somewhat surprising as previous reports using self-paced reading and eye-tracking only found differences at the NPs but not at the verb (e.g., Mazuka, Itoh & Kondo, 2002; also Miyamoto, 2006, for a summary). The reason why the difference was reliable in this experiment, contrary to what has been previously reported, may be related to the interaction reported next.

There was an interaction between verb frequency and word order at the matrix verb ($F_1(1,31) = 4.7$, $P < 0.05$; $F_2(1,22) = 4.53$, $P < 0.05$) as the canonical order was faster than the scrambled order for verbs with low frequency ($F_1(1,31) = 10.75$, $P < 0.005$; $F_2(1,11) = 13.48$, $P < 0.005$), but the difference was not statistically reliable for the verbs with high frequency ($F_1(1,31) = 2.25$, $P = 0.143$; $F_2(1,11) = 1.36$, $P = 0.27$) although the trends were in the same direction. It is likely that previous studies primarily used relatively frequent verbs, and that would explain why they did not find any reading time differences at the verb.

The interaction effect is interesting because it suggests that the sentence-level factor (i.e., word order) and lexical processes (which are most directly affected by verb frequency) are having a compounding effect on reading time latencies and are not simply additive. There are at least two ways in which the result can be explained. One possibility is that the result is really related to lexical frequency
(i.e., how often the verbs are used) and the interaction could be a sign that the prediction of the upcoming predicate is being hindered by the scrambled order and that becomes particularly disruptive when a low frequency verb is read. An alternative explanation is that it is not the frequency of the verbs that is important, but rather the frequency with which each verb is seen with each type of word order. In this case, scrambling per se is not important, and as long as a verb is often seen with scrambled NPs its reading times should be relatively fast. Correlation analyses reported in the next section were conducted in order to tease apart those two types of explanations, however the results were inconclusive and further studies are necessary.

5.2 Correlation analyses

Correlation analyses were conducted using the mean raw reading times to the main verb (‘called’ in (8a, b), ‘praised’ in (9a, b)) calculated separately for each word order.

Reading times correlated with the number of hits for the corresponding verb returned by Google (correlation with number of hits: $r=-0.35$, $P<0.05$; correlation with the logarithm of the number of hits: $r=-0.43$, $P<0.005$); hence, the more frequent the verb, the faster it was read regardless of word order. This is the general effect that high-frequency words are read faster.

Searches were also entered on Google as $ga\star oV$ for the canonical order, and $o\star gaV$ for the scrambled order, where V was the exact form of the verbs in the penultimate region of the test sentences, and $\star$ is the regular-expression wild card that can stand for any sequence of letters. There was a negative correlation between the number of hits for each verb in each word order and the mean reading times in the corresponding condition (raw: $r=-0.29$, $P<0.05$; log: $r=-0.42$, $P<0.005$). In other words, even when the frequency of each word order appearing with a verb is taken into consideration, the correlations are no better than the correlations conducted with the frequency of the verb alone. Because the frequency
of each verb highly correlates with the frequency of the same verb accompanied by each word order (raw: $r=0.67$, $P<0.0001$; logs: $r=0.8$, $P<0.0001$), it is unclear whether lexical frequency alone or the frequency of the verb with each word order is causing the effect. Corpus counts were also conducted on over 9.5 million newspaper sentences with similar results.

In short, the results indicate that the reading times at the verb correlate with the frequency of each verb in isolation as well as with the frequency of each verb preceded by each word order. Because these two types of frequencies are highly correlated, it is not clear which one contributes the most to the reading time effect. On-going work is exploring these alternative explanations.

6. Conclusion

The processing of head-final clauses in Japanese was argued to be processed incrementally in that NPs are associated together before the predicate is read or heard. Although previous studies provide strong evidence for syntactic representations to be built in order to associate the NPs in such situations, it is far less clear how much semantic interpretation is taking place and the kinds of information, apart from case markers, that are used in order to predict the clause-final verb. Two on-going research projects were summarized trying to provide more information on those processes. The results of three questionnaires were reviewed in support of the claim that possessor relations are used in order to associate NPs together. Moreover, a reading experiment was discussed investigating the effects of frequency on the processing of different word orders.

References


Miller, G. (1963). The magical number seven, plus or minus two: Some limits on our capacity for processing information. In R. Luce, R. Bush and E. Galanter (Eds.) *Readings in mathematical psychology, 1* (pp. 135-151).
New York: John Wiley & Sons.


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