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# Backward-Integration in Japanese: Evidence from Event-Related Brain Potentials

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## 1. Introduction

Recent research on sentence processing has revealed that an antecedent is integrated in real time with an element to be associated with. For example, a fronted wh-element (antecedent) is immediately integrated at the gap position. Furthermore, it has been reported that some specific event-related brain potential components (i.e., P600, sustained-left anterior negativity (LAN)) are elicited, reflecting such an integration process (King & Kutas, 1995; Kaan et al., 2000; Fiebach et al., 2001, 2002; Ueno & Kluender, 2003). Previous studies were all concerned with forward-integration processes in which the language processor already knows what antecedent (e.g., wh-element) is to be integrated with the gap (e.g., wh-trace). However, the obligatory dependencies between syntactic elements are not limited to forward-integration. To illuminate the integration mechanism in on-line sentence processing, it is necessary to examine not only forward-integration but also backward-integration processes. In backward-integration, the language processor recognizes the triggering element for integration at a later point in the string of elements. That is, the element to be integrated appears prior to the element that requires the integration. In the following sentence, for example, the quantified element (*gakusei* ‘student’) precedes the numeral quantifier (*san-nin*



Unfall den Doktor verständigt hat.  
 accident the<sub>[ACC]</sub> doctor called has  
 ‘Thomas asks himself who has called the doctor after the accident on Tuesday afternoon.’

b. object wh question

Thomas fragt sich, wen<sub>i</sub> am Dienstag nachmittag nach dem  
 Thomas asks himself, who<sub>[ACC]</sub> on Tuesday afternoon after the  
 Unfall der Doktor t<sub>i</sub> verständigt hat.  
 accident the<sub>[NOM]</sub> doctor called has  
 ‘Thomas asks himself who the doctor has called after the accident on Tuesday afternoon.’

Results of the experiment showed that wh-movement of the object NP into the clause-initial position elicited a sustained-LAN when compared to wh-movement of the subject. This negativity was observed from the first prepositional phrase (*am Dienstag* ‘on Tuesday’) until the subject noun phrase (*der Doktor* ‘the<sub>[NOM]</sub> doctor’). Furthermore, a P600 for the object wh-question was observed in local ERPs at the second noun phrase position (*der Doktor*). Regarding the sustained-LAN, Fiebach et al. conclude that it reflects the storage of the wh-filler in the working memory until the syntactic dependency between the dislocated filler and its gap is established. On the other hand, the P600 was interpreted as indexing the establishment of the syntactic dependency between the filler and its gap. These two ERP components have been observed not only in German wh-questions but also in English wh-questions and in Japanese scrambling constructions (Kaan et al., 2000; Ueno & Kluender, 2003).

## 1.2 Backward-integration in parsing

Numeral quantifiers in Japanese can freely appear in various positions in a sentence, and thus they are known as floating quantifiers (FQ). Some examples are shown in (4) below.



begins to search for the element to be integrated.

All previous studies designed to explain the integration processes have done so by addressing forward-integration processes. However, the obligatory dependencies between syntactic elements are not limited to forward-integration. To illuminate the integration mechanism in on-line sentence processing, we need to examine not only forward-integration but also backward-integration processes. To address this issue, we examined when and how backward-integration is pursued by recording event-related potentials when participants read Japanese sentences containing FQs.

(7)a. Short-distance Condition (SC)

Gakusei-ga kinoo konbini-de zasshi-o san-satsu katta.  
 student-NOM yesterday at store magazine-ACC three-volumes bought  
 'Yesterday, a student bought three magazines at the store.'

b. Long-distance Condition (LC)

?Gakusei-ga kinoo konbini-de zasshi-o san-nin katta.  
 student-NOM yesterday at store magazine-ACC three-persons bought  
 'Yesterday, three students bought a magazine at the store.'

c. Adverb Condition (AC)

Gakusei-ga kinoo konbini-de zasshi-o san-kai katta.  
 student-NOM yesterday at store magazine-ACC three times bought  
 'Yesterday, a student bought a magazine three times at the store.'

In (7a)SC, *-satsu* is a numeral quantifier that modifies a noun such as a book, magazine, or dictionary. When *san-satsu* appears, the language processor may examine whether or not the possible host-NP has already been input. Then, the language processor may try to integrate the FQ with its host-NP if a suitable noun (e.g., *zasshi-o* magazine-ACC) has already been input. In this case, it is assumed that the language processor can perform backward-integration easily because the FQ is adjacent to its host-NP. The quantifier *-nin* is a numeral quantifier which modifies persons, as in (7b)LC. When *san-nin* is presented, it is assumed that the language processor will search for a host-NP which the FQ can modify. Contrary to SC, the language processor cannot integrate the FQ with the

adjacent NP (*zasshi*) in LC. Therefore, we predict that the processing cost will be higher in the LC than in the SC. The quantifier *-kai* cannot modify the noun and can only modify the verb in (7c)AC (Iida, 1999). Therefore, even if '*san-kai*' is presented, the language processor may not start the host-searching process.

Given that the processes described above occur, two experimental outcomes can be predicted. First, since the operation of the integration of the FQ with its host-NP is added in the SC and the LC but not in the AC, P600 will be elicited accordingly to reflect such integration difficulty (Kaan et al., 2000; Fiebach et al., 2001, 2002; Ueno & Kluender, 2003; Kaan & Swaab, 2003). Second, the language processor will integrate the FQ with the most recent NP in the SC. On the other hand, the FQ will not be integrated with the most recent NP and instead be integrated with the distant host-NP in the LC. Therefore the processing cost will be larger, and in turn the amplitude of P600 will be greater, in the LC than in the SC<sup>1</sup>.

## 2. Experiment

### 2.1 Participants

Twenty four native speakers of Japanese participated in the experiment (15 females; mean age, 21.9). All were right-handed and had normal or corrected-to-normal vision. They were paid for their participation.

### 2.2 Stimuli

Three experimental conditions such as those described in (7) were examined. There were 90 sets of three experimental conditions. We divided the 90 sets of experimental sentences into three material lists according to a Latin square design. One hundred and fifty other sentences were added as fillers, and each list was pseudo-randomized.

### 2.3 Procedure

All sentences were presented bunsetsu by bunsetsu on a TFT screen<sup>2</sup>. First, a star (★) was presented on the center of the screen for 3000msec for the purpose of

fixation. Next, each word was shown as replacing the preceding word and was presented for 600msec with an ISI of 100msec. Participants were instructed to silently read each sentence for comprehension, and an acceptability judgment task was imposed for all sentences. Participants answered whether or not the sentence was acceptable by pressing one of the two mouse buttons after each sentence was presented. In order to maintain the concentration of the participants, a five-minute break was inserted at five-minute intervals.

## 2.4 EEG recording

An electroencephalogram (EEG) was recorded for each participant from seven positions. All electrodes were placed according to the international 10/20 system (Jasper, 1958), at Fz, F7, F8, Cz, Pz, P3, and P4. The linked earlobe served as a reference. All electrode impedances were kept below 5k $\Omega$ . Additional electrodes were placed beneath the left eye to monitor eye-movements and blinks for later rejection. The EEGs were amplified with a bandpass of 0.01-50Hz, and the sampling rate was 200Hz.

## 2.5 Results

All EEG and electrooculogram (EOG) records were examined for artifacts and for excessive EOG amplitude (> 50 $\mu$ V) within the windows of analyses. The rejection rate due to blinking and other problems was approximately 7%. Averages were aligned to a 100msec baseline preceding the target FQs (i.e., *san-sastu*, *san-nin*, *san-kai*).

Based on the visual inspection, an ANOVA was performed in three epochs after the presentation of the FQs. Both 'sentence type' (three conditions) and 'electrode sites' (seven positions) were within-subject factors. In the first epoch (300–350msec), both the main effects of the sentence type and the electrode sites were significant (sentence type:  $F(2, 46) = 4.50, p < .05$ , electrode sites:  $F(6, 138) = 46.13, p < .001$ ). The interaction between the sentence type and the electrode site was not significant ( $F(12, 276) = 0.69, n.s.$ ). The multiple comparison (Ryan's method) on the main effect of the sentence type showed that the SC and the LC shifted negatively compared to the AC3. In the second epoch (350–500msec), both the main effects of the sentence type and the electrode sites were significant

(sentence type:  $F(2, 46) = 9.95, p < .001$ ; electrode sites:  $F(6, 138) = 21.95, p < .001$ ). The interaction between the sentence type and the electrode site was not significant ( $F(12, 276) = 1.68, n.s.$ ). The multiple comparison (Ryan's method) on the main effect of the sentence type showed that the LC shifted negatively compared to the other two conditions<sup>4</sup>. In the third epoch (500–800msec), both the main effects of the sentence type and the electrode sites were significant (sentence type:  $F(2, 46) = 6.24, p < .005$ ; electrode sites:  $F(6, 138) = 2.61, p < .05$ ). The interaction between the sentence type and electrode sites was significant ( $F(12, 276) = 5.37, p < .001$ ). The simple main effect of the sentence type was significant at Fz ( $F(2, 322) = 5.40, p < .005$ ). This indicated that the LC and the AC shifted positively compared to the SC<sup>5</sup>.

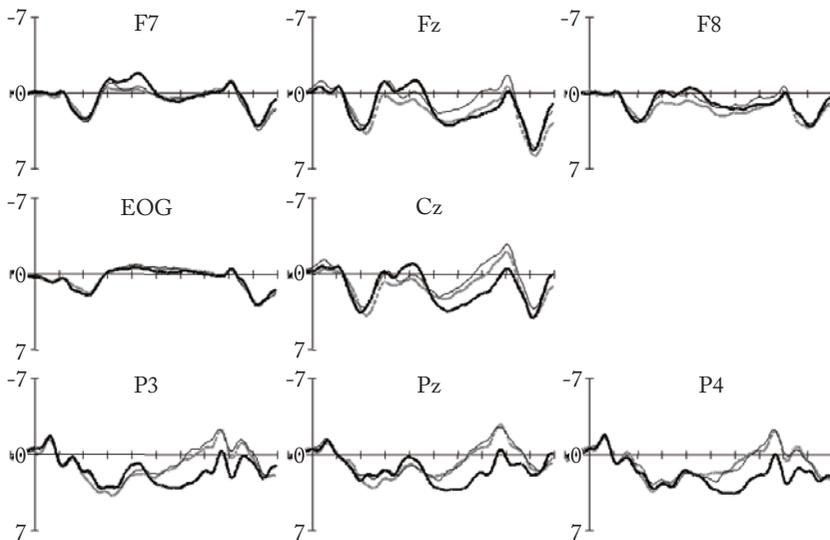


Figure 1. Grand average ERPs ( $N=24$ ) from the seven electrode sites for the waveform during -100~1000msec elicited by the FQs. solid line: (7a) short condition, bolder line: (7b) long condition, dotted bolder line: (7c) adverb condition

At Cz, Pz, P3, P4, the LC shifted positively compared to the SC and the AC<sup>6</sup>. The polarity and latency of these results indicate that this positivity should be P600 (Osterhout & Holcomb, 1992; Osterhout, 1994; among others).

### 3. Discussion

#### 3.1 The negativity elicited in the SC and the LC

In the first epoch (300–350msec), the SC and the LC shifted negatively relative to the AC. We interpreted this negativity as the processing cost of the language processor for recognizing ‘*san-satsu*’ and ‘*san-nin*’ as FQs and beginning to search for their host-NPs. Fodor & Inoue (1994) have indicated that syntactic reanalysis is performed in two stages: first ‘diagnosis’ and then ‘repair’. That is, the language processor first examines whether or not reanalysis is needed and, if so, determines how it should be conducted (‘diagnosis stage’). Then the actual reanalysis is conducted (‘repair stage’). Before we actually do something, we have to judge whether it is worth doing. In general, the judgment process precedes the actual performance. In establishing the dependencies between syntactic elements, these two processes are essential, as is shown in (8) below. In our experiment, the judgment process (8a) may have elicited the negativity found in this epoch (300–350msec). We therefore call this negativity “judgment negativity” (see also Yasunaga & Sakamoto, 2006).

- (8)a. The judgment process, which examines whether the input element needs to be integrated with another element.
- b. The actual integration operation, which associates two syntactic elements.

#### 3.2 The negativity and the P600 elicited in the LC

Ueno & Kluender (2003) recorded the ERPs when the participants read Japanese scrambling constructions, and reported that P600 was elicited followed by the phasic-LAN at the point where the filler-gap integration was assumed to be performed. They interpreted this phasic-LAN as reflecting the processing cost that the language processor picked up the filler from the working memory, and the P600 as reflecting the processing cost that the actual integration process of filler-gap dependency was performed.

In the second epoch (350–500msec), the negativity was elicited in the LC compared to the SC and the AC. This negativity can be different from the negativity observed in Ueno & Kluender’s study. As mentioned above, they interpreted



SC, we consider the processing cost of SC as relatively smaller than that of LC.

## 4. General discussion

### 4.1 The direction of integration

Experimental results have suggested that the language processor performs the following three processes: (i) it recognizes the FQ as the element requiring integration with its proper host-NP, (ii) it searches the proper host-NP in the working memory, and (iii) it integrates the FQ with the host-NP shortly after the input of the FQ. These three processes seem to be reflected as (i) negativity (300–350msec), (ii) negativity (350–500msec), and (iii) P600 (500–800msec) respectively. These results suggest that backward-integration is performed in real time, just as in the case of forward-integration. The universality of the integration process is reflected in its immediacy (on-line character), while the difference in direction (forward vs. backward) is reflected in the differences in working memory patterns. That is, very interestingly, the cost placed on the working memory in backward-integration was found to be distinct from that in forward-integration. In forward-integration, the cost placed on the working memory increased when the language processor holds elements until the integration is performed (i.e., “holding cost”). In backward-integration, on the other hand, the cost placed on the working memory increased when the language processor searches elements to be integrated (i.e., “searching cost”). This distinction is reflected on the ERP pattern such as the negativity elicited in 350–500msec.

### 4.2 The P600 elicited in the AC

We predicted that the P600 was not elicited in the AC since *san-kai* was an adverb that does not require the integration with the proper host-NP. The positivity, however, was observed at Fz peaking around 600msec. Some sort of processing cost may have increased in the AC, when the input of the *san-kai*. It may be the case that a quantificational expression in general elicits a P600-like component. However, it is hard to judge at this stage what kind of process this positivity reflects. Thus, we will leave this question open.

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## Notes

1. It has been suggested that the amplitude of P600 is a function of the processing cost (Osterhout et al. 1994; among others)
2. A *bunsetsu* means a unit of Japanese which consists of one free morpheme, or one free morpheme with bound morpheme/s (particles modifying the noun or verb such as case markers), and will be referred as a "word" hereafter.
3. SC-AC:  $t(46) = 2.58, p < .05$ ; LC-AC:  $t(46) = 2.62, p < .05$ ; SC-LC:  $t(46) = 0.04, p > .1$ .
4. SC-AC:  $t(46) = 4.21, p < .001$ ; LC-AC:  $t(46) = 3.39, p < .005$ ; SC-LC:  $t(46) = 0.82, p > .1$ .
5. SC-LC:  $t(322) = 2.88, p < .005$ ; AC-LC:  $t(322) = 2.81, p < .01$ ; SC-AC:  $t(322) = 0.76, p > .1$

	SC - LC	SC - AC	LC - AC
Cz	$t(322) = 2.39, p < .05$	$t(322) = 1.38, n.s.$	$t(322) = 3.77, p < .001$
Pz	$t(322) = 3.67, p < .001$	$t(322) = 0.16, n.s.$	$t(322) = 3.81, p < .001$
P3	$t(322) = 3.64, p < .001$	$t(322) = 0.64, n.s.$	$t(322) = 4.29, p < .001$
P4	$t(322) = 3.06, p < .005$	$t(322) = 0.03, n.s.$	$t(322) = 3.06, p < .005$

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