ERP Correlates of the Processing of Object-Verb Integration in Japanese

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1. Introduction

It is essential for language comprehension to integrate phrases into whole structures and meanings. This integration most likely involves syntactic, semantic, pragmatic, and other aspects of written or uttered sentences. In the present study, we explored integration processes involved in the reading of simple Japanese sentences, focusing on a syntactic aspect regarding the dependency between verbs and case markers. In Japanese, it is known that a group of transitive verbs selectively takes an accusative object while another group takes a dative object (Inoue, 1983; Takezawa & Whitman, 1998). These constraints are structurally characterized by the fact that: (i) the cases of objects are marked by the postpositional case particles (i.e., "O" for the accusative and "Ni" for the dative) and (ii) such a case-marked object usually precedes a critical verb in a sentence. Thus, immediately after the appearance of a verb, a match or mismatch between an object and a verb can be processed or even reanalyzed (see sentence samples below).

Since the Japanese transitive verbs "subcategorize" their objects, the mismatch between the case-marked noun phrases (NPs) and specific verbs invites a subcategorization violation. The present study investigated how this mismatch (i.e., subcategorization violation), as compared to no-mismatch, would be reflected in

event-related brain potentials (ERPs). We were interested in characterizing the processing of these sentences in light of accumulating ERP findings in languages (see Friederici, 2002; Kutas, Federmeier, Coulson, King, & Muente, 2000, for reviews). Our intention was also to look at the present results from a cross-linguistic point of view and to obtain insight into the ongoing lines of discussion in language studies.

Each sentence used in the present study consisted of three phrases (or *bunsetu* in Japanese): a subject marked with the nominative particle "Ga", an object marked with either the accusative particle "O" or the dative particle "Ni", and a critical verb that can co-occur with either the accusative object or the dative object. Sentences were classified as correct if there was no mismatch between a verb and an object (samples 1a and 2a below: NOM=nominative, ACC=accusative, DAT=dative). On the contrary, sentences were classified as incorrect if there was any mismatch between them (samples 1b and 2b below). Note that correct and incorrect sentences mirrored each other except that their second phrases had different particles, so that they constitute minimal pairs.

(1)a.   *Toshiko-ga Kazuo-o houmonshita.*
       -NOM   -ACC visited
    'Toshiko visited Kazuo.'
  b.   * *Toshiko-ga Kazuo-ni houmonshita.*

(2)a.   *Toshiko-ga Kazuo-ni sokutoushita.*
       -NOM   -DAT answered
    'Toshiko answered Kazuo (immediately).'
  b.   * *Toshiko-ga Kazuo-o sokutoushita.*

The distinction between these two types of Japanese verbs can be commonly found in corpus-based analyses (Ikehara et al., 1997). It was also shown in a rating experiment that correct sentences of the above type were perceived to be far more natural than those incorrect sentences (Arao, Suwazono, & Sakamoto, 2003). These off-line data, though reflecting simply a consequence of overall processing, indicate that these mismatches appear to be clearly noticeable to native speakers

of Japanese. Our initial prediction was that these mismatches would be reflected in some ERP indices, specifically such as those observed in correlation with syntactic anomalies. In the following section, we briefly review relevant ERP components and provide some specific predictions.

ERPs are sequential voltage deflections captured with millisecond precision and promising in that they allow one to track cognitive processes with a fine time resolution. For instance, an early negative component and a late positive component have been assumed to reflect different processes that are closely related to syntactic processing. The earlier one, the ELAN (early left anterior negativity), is typically triggered by phrase-structure and word-category violations, and appears to reflect highly automatic first-pass parsing (e.g., Hahne & Friederici, 1999, Neville, Nicol, Barss, Forster, & Garrett, 1991). This component usually appears about 150–200 ms after the onset of critical words at left frontal sites, suggesting that processing of such anomalies takes place very early in time. The later one, the P600, is typically triggered by garden-path sentences (i.e., sentences structured in a non-preferred manner), and appears to reflect reanalysis or revision of syntactic structures (e.g., Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994). This component usually appears about 600 ms after the onset of critical words mainly at centro-parietal sites, suggesting that such costly processing takes place at that time window significantly later than the ELAN range. In addition to these components, the N400, conventionally thought to reflect lexical-semantic processing (e.g., Kutas & Hillyard, 1980, 1983), has been reported in a German study to reflect case-ambiguity resolution in situations where no major revision of phrase structure is required (Bornkessel, McElree, Schlesewsky, & Friederici, 2004). As the name implies, the latency of this component typically falls in between the ELAN and P600 components. Other studies in German also reported an N400 or a N400/P600 complex in response to case-related anomalies (Frisch & Schlesewsky, 2001, 2005; Hopf, Bayer, Bader, & Meng, 1998), suggesting that the N400 and the P600 would reflect thematic interpretive processes and structure building processes, respectively (Frisch & Schlesewsky, 2001). In the latency range around 400 ms, a left-lateralized anterior negativity (LAN) was also reported to be triggered by several patterns of morphosyntactic illformedness, and was interpreted as reflecting a specific

response to such illformedness (Hagoort & Brown, 2000; Münte, Matzke, & Johannes, 1997).

It is, of course, too simplistic to postulate a direct one-to one correspondence between these ERP components and our actual mental processes. For example, a late component may reflect the mental process that occurs in an early stage of processing. As is mentioned above, however, the previous studies accumulated various evidence that there must be some correlation between some ERP components and specific computational subprocesses. We thus assume that if any of the processes similar to those above would occur while processing our sentences, those corresponding ERP effects would be observed in the present study. If this sort of syntactic information would play a critical role in first-path parsing processes that quickly detect and mend anomalies, an ELAN would appear for those mismatches between verbs and case particles. If mismatches would trigger effortful revision processes, as is often the case with the processing of garden-path sentences, a P600 would be elicited. Similarly, the occurrence of processes similar to case ambiguity resolution without major revision of structures could be suggested by the appearance of an N400. If none of these processes or only some different processes were in operation, different ERP patterns would be obtained.

In Experiment 1, participants were required to read sentences silently. Our purpose here was to investigate pure reading processes, minimizing possible co-occurrences of processes arising from task demands other than reading. Note that, in this experimental task, there was no observable indication that the participants noticed the mismatch between the preceding NPs and specific verbs. Thus, we cannot exclude the possibility that they were only exposed to but did not attend to the anomalies while performing the reading task.

2. Experiment 1

2.1 Method

Participants: Fourteen paid volunteers (ages 18–23, 7 males) participated in the experiment after giving their informed consent. All were native speakers of Japanese. They all had normal or corrected-to-normal vision, and were determined to

be right-handed by the Edinburgh Inventory (Oldfield, 1971). The study was car-
ried out in accordance with the human research guidelines of the Internal Review
Board of the University of Niigata.

Materials: Two groups of 32 verbs (64 in total) were selected from a pool of Japa-
nese verbs that matched in familiarity based on large corpus data (Ikehara et al.,
1997): One group requires the accusative case particle "O" and the other requires
the dative case particle "Ni". All these verbs showed clear case preference, as re-
vealed by the data reported by Arao, Suwazono, & Sakamoto (2003) (i.e., sentenc-
es were perceived to be far more natural when the case particle was matched to the
requirement of the verb than when it was not). The "O"- and "Ni"-verbs did not
significantly differ in familiarity, the number of moras, and the number of Kanji
and Hiragana characters.

There were 32 correct and 32 incorrect experimental sentences based on the
"O"-verbs and 32 correct and 32 incorrect sentences based on the "Ni"-verbs (128
sentences in total). Each sentence consisted of a subject noun (male or female
name), an object noun with an "O"/"Ni" particle, and one of the "O"- and "Ni"
-verbs. The correct sentences had no mismatch between the verb and the case par-
ticle, whereas the incorrect sentences had a mismatch between them. Note that
the only difference between the correct and incorrect sentences was the particle.
These 128 sentences were duplicated with different noun (name) pairs for the ex-
periment (256 sentences in total).

Procedure: Using a STIM system (Neuroscan Labs Inc., El Paso, US), stimulus
sentences in white characters on a black background were visually presented one
phrase at a time. The subject and object phrases had a duration of 700 ms, the verb
phrases had a duration of 800 ms, and the stimulus onset asynchrony (SOA) was
1.3 seconds for both. Participants were required to silently read and try to best un-
derstand the sentences without making any overt reactions or judgments. At the
beginning of each trial, a plus sign appeared at the center of the screen and served
as a fixation point. This sign was presented 2.8 s after the appearance of the last
stimulus (a verb) in the preceding trial. The participants sat in a comfortable chair
in an air-conditioned, normally lit room.

Recording: Silver electrodes were attached on Fp1, Fp2, Fpz, Fz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, Pz, P3, P4, O1, O2, and Oz points, following the international 10–20 method (Jasper, 1958). Two additional electrodes were attached lateral to the left eye (hEOG) and below the left eye (vEOG) in order to monitor the electrooculogram. All channels were referred to the linked earlobes with the impedances kept below 5 kΩ during the recording sessions. Using a 32-channel SynAmp (Neuroscan Labs Inc., El Paso, US), 16-bit electroencephalogram (EEG) data were acquired at a gain of 500, sampled at a rate of 1 kHz, filtered with a bandpass of 0.05–100 Hz, and then stored digitally. EEG data were segmented to set the analysis period from 100 ms prior to 900 ms after the onset of each stimulus. After the baseline was corrected by subtracting the average of pre-stimulus period, artifact rejection was performed with the threshold of ± 100 μV from the baseline at Fp1, Fp2, Fpz, F7, F8, T3, T4, hEOG, and vEOG. The ERPs were obtained by averaging EEG segments time-locked to stimulus onset for each verb-particle combination, and then all averages were low-pass filtered at 30 Hz (24dB/oct). Analyses of variance (ANOVAs) on ERP data were performed with Greenhouse-Geisser adjustments, and the following results reflect these adjustments.

2.2   Results and discussion

There were no apparent indications of the ELAN, LAN/N400, and P600 effects (Figure 1). Interestingly, however, amplitudes were apparently larger for correct sentences than for incorrect sentences within a latency range of 500–800 ms (i.e., the P600 range) at Fz. This effect appeared to occur for both "O"- and "Ni"-verbs. This effect was clearly different from the conventional P600 effect where amplitudes were larger for incorrect sentences than for correct sentences most clearly at centro-parietal sites. Mean ERP amplitudes within this latency range at midline sites (Fz, Cz, and Pz) were entered into an ANOVA with factors of Verb ("O" and "Ni"), Grammaticality (correct and incorrect), and Electrode Site (Fz, Cz, and Pz). There was a significant interaction between Grammaticality and Electrode Site ($F(2,26)=4.65$, $p< .05$). The effect of Grammaticality was significant only at Fz ($F(1,13)=5.55$, $p< .05$) but not at Cz and Pz in separate ANOVAs. The other effects and interactions did not attain statistical significance. The statistical results were in agreement with the above observation.
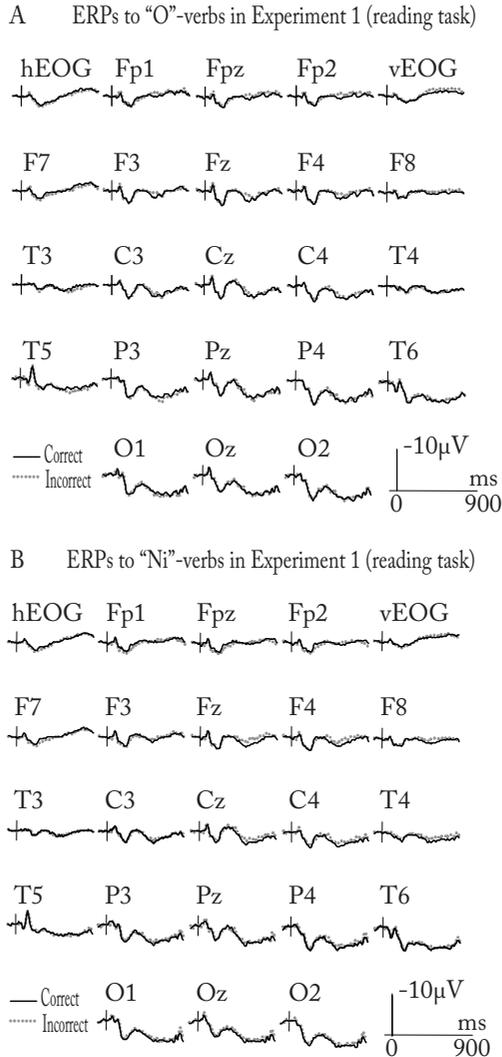
A   ERPs to "O"-verbs in Experiment 1 (reading task)

hEOG Fp1   Fpz   Fp2   vEOG

F7   F3   Fz   F4   F8

T3   C3   Cz   C4   T4

T5   P3   Pz   P4   T6

—— Correct   O1   Oz   O2   -10μV
······ Incorrect   ms
                                          0   900

B   ERPs to "Ni"-verbs in Experiment 1 (reading task)

hEOG Fp1   Fpz   Fp2   vEOG

F7   F3   Fz   F4   F8

T3   C3   Cz   C4   T4

T5   P3   Pz   P4   T6

—— Correct   O1   Oz   O2   -10μV
······ Incorrect   ms
                                          0   900

Figure 1. *Grand average ERPs to "O"- and "Ni"-verbs in correct and incorrect sentences in Experiment 1. A: ERPs to "O"-verbs. B: ERPs to "Ni"-verbs. Negativity is plotted up. Vertical ticks for each channel indicate the stimulus onset.*

These results are in clear contrast to the conventional findings regarding syntactic anomalies. We initially postulated that incorrect sentences could trigger one or some combinations of the ELAN, LAN/N400, and P600 effects, all of which were reported to reflect some aspects of syntactic processing. The results, however,

showed no indication of these effects in the present experiment. No direct support was thus obtained for the activation of psycholinguistic processes that were thought to be associated with these ERP components. The other notable aspect is that grammatical sentences were associated with a more positive waveform within the latency range of 500–800 ms at Fz. Thus, some aspect of grammaticality appears to be processed in this time range. At a glance, these results imply that there could be essential differences between processes involved in the reading of these Japanese sentences and those involved in the reading of sentences in other languages.

Before concluding that Japanese sentence processing contrasts with that of other languages, we decided to conduct Experiment 2 to clarify the effects of task demands on ERPs. Although it was reported that some grammaticality-related ERPs were highly automatic (Hahne & Friederici, 1999) or took place within various tasks (Hahne & Friederici, 2002; Kaan & Swaab, 2003), the less-demanding reading task could contribute to the absence of the grammaticality-related ERPs in Experiment 1. Specifically, within the simple reading task, the processing could succeed at a relatively superficial level, reducing attentional resources allocated to grammatical processing. In Experiment 2, care was taken to allocate much attention to the grammaticality of sentences, by employing a correction task that imposed participants not only to decide the grammaticality of sentences but also to consider the correction of ungrammatical case-particle usages.

3. Experiment 2

3.1   Method

Participants: Nine paid volunteers (ages 18–24, 6 males) participated in the experiment after giving their informed consent. All were native speakers of Japanese. They all had normal or corrected-to-normal vision, and were determined to be right-handed by the Edinburgh Inventory (Oldfield, 1971). The study was carried out in accordance with the human research guidelines of the Internal Review Board of the University of Niigata.

Materials: The same materials as in Experiment 1 were used.

Procedure: The same procedure as in Experiment 1 was used except for the following aspects. Participants were required not only to judge whether sentences were correct or not, but also to correct case-marker particles if sentences were incorrect. Two processes were assumed to be involved: judgment process and correction process. The judgment process was expressed by pressing either button 1 (if sentences were judged to be correct) or 2 (if sentences were judged to be incorrect). When the participant judged a sentence as incorrect, (s)he was required to reproduce a correct sentence by replacing the case particle. This process of correction was performed within the participant's mind. Thus, this mute process was unable to be observed from the outside. For each trial, the presentation of the critical verb was followed by a response cue at an SOA of 1.3 s. After the cue, responses were made.

Recording: The conditions of electrophysiological recording were identical to those in Experiment 1.

3.2   Results and discussion

In marked contrast to Experiment 1, clear ERP effects were observed both in the LAN/N400 latency range and in the P600 latency range (Figure 2). As for the LAN/N400 range, midline and lateral data within the latency range of 300–500 ms were treated separately to perform quantitative analysis of hemispheric differences. A midline ANOVA performed in the same manner as in Experiment 1 yielded only a marginally significant effect of Grammaticality ($F(1,8)=4.90$, $p<.1$). An ANOVA on lateral data from 12 electrode sites (F3, F4, F7, F8, C3, C4, T4, T5, P3, P4, T5, and T6) was performed with factors of Verb ("O" and "Ni"), Grammaticality (correct and incorrect), Hemisphere (left and right), and Electrode Position (anterior: F3/4, F7/8, middle: C3/4, T3/4, and posterior: P3/4, T5/6). There was a significant 2-way interaction between Hemisphere and Grammaticality ($F(1,8)=8.18$, $p<.05$) and a significant 3-way interaction between Verb, Grammaticality, and Hemisphere ($F(1,8)=5.72$, $p<.05$). These interactions were further qualified by a 4-way interaction between Verb, Grammaticality, Hemisphere, and Electrode Position ($F(2,16)=6.97$, $p<.05$). As for "O"-verbs, subsequent

A   ERPs to "O"-verbs in Experiment 2 (correction task)

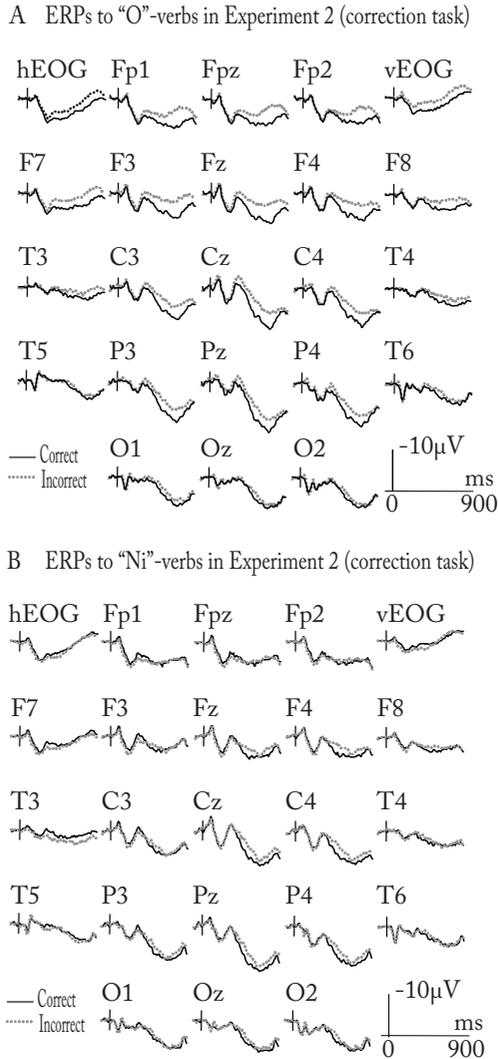B   ERPs to "Ni"-verbs in Experiment 2 (correction task)

Figure 2. *Grand average ERPs to "O"- and "Ni"-verbs in correct and incorrect sentences in Experiment 2. A: ERPs to "O"-verbs. B: ERPs to "Ni"-verbs. Negativity is plotted up. Vertical ticks for each channel indicate the stimulus onset.*

separate ANOVAs revealed that the effect of Grammaticality was significant only at the left anterior region ($F(1,8)=6.52$, $p<.05$). As for "Ni"-verbs, separate ANOVAs revealed that the effect of grammaticality was significant only at the right middle region ($F(1,8)=11.72$, $p<.01$). Thus, the patterns of results for "O"- and

"Ni"-verbs differed. Case mismatches caused by "O"-verbs triggered a left-lateralized anterior negativity (i.e., clear signs of the LAN effect). Those by "Ni"-verbs, showing no indication of anterior negativity, triggered a right-lateralized centro-temporal negativity (i.e., an N400-like effect).

In the P600 latency range, a very large positive-going shift took place with a broad distribution. Importantly, although this positive shift was clearly modulated by grammaticality, the effect was again in the reverse direction of the conventional P600 effect. The current effect was characterized by larger amplitudes for correct sentences, whereas the conventional P600 effect by larger amplitudes for incorrect sentences. An analogous ANOVA on midline data was performed for the latency range of 500-800 ms. The ANOVA revealed a significant effect of Grammaticality ($F(1,8)=17.95$, $p<.005$).

Overall, several distinctive ERP effects were revealed by introducing the correction task instead of the reading task. The task effect was specifically reflected in the emergence of LAN/N400 effects and the broad and salient development of a later positive component. These components were well modulated by the grammaticality factor, suggesting that mismatches were actually dealt with at multiple processing stages that were also strongly influenced by the attentional demands on the syntactic aspects of sentences.

4. General Discussion

As revealed in Experiment 1, the processing of mismatches between verbs and case particles involved in simple reading was characterized by a frontal positive shift in the P600 latency range. This effect was equally pronounced for both "O"- and "Ni"-verbs. Importantly, since this component was larger for correct sentences than for incorrect sentences, the effect was in the reverse direction of the conventional P600 effect. The distribution of this component was also apparently different from the typical centro-parietal distribution of the conventional P600. In previous studies, only a few reported a more frontally-distributed P600 (Osterhout & Holcomb, 1992) or P600 subcomponent (Hagoort & Brown, 2000). For the present, we named the current effect the "inversed P600," and discussed in further de-

tail in the later section. The results of Experiment 1 also showed no indications of first-pass parsing (the ELAN effect; Hahne & Friederici, 1999), case-ambiguity resolution without major revision of structure (the N400 effect; Bornkessel, McElree, Schlesewsky, & Friederici, 2004), and costly syntactic revision (the P600 effect; Osterhout & Holcomb, 1992).

The only difference between Experiments 1 and 2 is the task given to the participants. In the former, they are simply asked to read the given sentences, in which the mental processing could be rather "shallow." While in the latter, they are required to press a button after the grammaticality judgment and reproduce correct sentences by replacing the case particle. In this task, the processing mechanism would be more "deep." This shallow-deep distinction is introduced in Clark & Clark (1977) explaining the results of Bobrow & Bower's (1969) experiment, in which a sentence like "The cow chased the rubber ball" was presented. The participants were instructed either to read aloud or to generate a sentence that could sensibly follow the given sentence in a story. Clark & Clark claim that the former task requires "rather shallow comprehension," and the latter "rather deep comprehension." Later, the participants were asked to retrieve the second noun (ball) in presenting the first noun (cow). Retrieval rates were lower in the reading task (22%) than in the sentence generation task (43%), leading those authors to argue that the difference in task requirements affects the "depth of processing."

In Experiment 2, when readers allocated their attention more to those mismatches, several distinct ERP effects of grammaticality emerged both in the LAN/N400 latency range and in the P600 latency range. In the LAN/N400 latency range, mismatches caused by "O"-verbs produced a LAN effect and mismatches caused by "Ni"-verbs produced an N400-like effect. Given that there was no indication of these effects in Experiment 1, the occurrence of these effects appears to require additional processing efforts other than simple reading, specifically those required for conscious grammaticality judgment and error correction. The actual processing reflected in these ERP effects is thus less automatic in the sense that simple reading of anomalous pairs does not bring in these effects.

The LAN and N400 effects are usually interpreted in different ways. The former is supposed to reflect responses to morphosyntactic illformedness (Hagoort & Brown, 2000; Münte, Matzke, & Johannes, 1997), and the latter thematic inter-

pretive processes (Frisch & Schlesewsky, 2001). If this general distinction applies to Japanese, our findings in Experiment 2 suggest a very interesting story. The "NP-ga NP-ni + O-verb" elicited LAN, while the "NP-ga NP-o + Ni-verb" elicited N400. Thus, it may imply that the mismatch (i.e., subcategorization violation) between the "Ni" marked NP and "O"-verb is indicative of morphosyntactic ill-formedness, while the mismatch between the "O" marked NP and "Ni"-verb is rather indicative of semantic incongruity. In other words, the requirement of an accusative NP from the "O"-verb would be morphosyntactic (or, structural) in nature, while the requirement of a dative NP from the "Ni"-verb could be thematic (or, semantic) in nature. The fact that even the same type of syntactic (subcategorization) violation is processed in different manners may indicate the essential difference between the two types of case particles.

There is another possible interpretation of the N400-like effect observed in Experiment 2. Since the critical verbs appeared at the sentences' final position in our experimental setting, this effect might also be viewed as reflecting semantic consequences of syntactic anomalies during sentence wrap-up processing (Osterhout, 1997). Note, however, that the N400-like effect here was observed only in responses to mismatches caused by "Ni"-verbs. If such wrap-up processing would operate, the processing of "O"-verb mismatches should have elicited the same N400-like effect. The lack of unitary effect may render the account based on the wrap-up effect untenable.

Mismatches also modulated a very large positive shift within the P600 range in Experiment 2. The amplitude of this component was lager for correct sentences than for incorrect sentences, irrespective of the verb type. Thus, although the late positivity had much lager amplitude and broader distribution in Experiment 2 than in Experiment 1, the effects found in both experiments could share something in common. Certain processes regarding those mismatches were activated even through the simple reading task in Experiment 1, and those processes could be similarly activated or even enhanced by the attentional demands required for the correction task in Experiment 2. Importantly, however, many studies commonly assumed that the amplitude of the P600 would reflect processing cost arising from syntactic mismatches or non-preferred structures (Kaan, Harris, Gibson, & Holcomb, 2000; Kuperberg, Caplan, Sitnikova, Eddy, & Holcomb, 2006; Os-

terhout, Holcomb, & Swinney, 1994). This line of reasoning leads to a puzzling scenario where such cost must be higher for correct sentences than for incorrect sentences in the present study.

Although speculative, we tentatively assume an account for this apparent paradox as follows. The Japanese language, with a head-final word-order principle, has a unique structural property that allows in principle infinite additions of succeeding phrases to a preceding series of phrases that may apparently already complete a sentence. Even if those preceding phrases involve a structural mismatch, the mismatches can often be even fully resolved by adding succeeding phrases. For instance, the wrong sentence (1b) can be resolved by means of this operation (3a).

(1)b.   * *Toshiko-ga Kazuo-ni houmonshita.*
                    -NOM   -DAT visited

(3)a.   *Toshiko$_i$-ga Kazuo-ni [pro$_{i/j}$ houmonshita basho] –o sokutoushita.*
                    -NOM   -DAT   visited   place –ACC answered
        'Toshiko (immediately) answered Kazuo about the place she visited.'

As such, if the Japanese parser takes a strategy characterized by immediate mending of mismatches, the mending can be even more costly. The mended portions can be later falsified and should be mended again. Given that earlier phrases in a sentence are often ambiguous in syntactic and semantic respects, the immediate mending of those earlier phrases may give rise to more serious drawbacks in processing. For this reason, anomalous sentences of the present type may tend to be processed rather halfway, often bypassing those immediate mending processes. Since this way of processing withholds conclusive interpretation of phrases, it can incorporate further phrasal input with greater flexibility and less processing resources. The reasoning above leads to the prediction that correct sentences have more chance to be fully processed than incorrect ones. In other words, the termination or boundary of sentence processing may be clearer for correct sentences than for incorrect sentences, resulting in relative acceleration of context-updating processes (Donchin & Coles, 1988) for correct sentences. Thus, more processing cost or resources are consumed in the processing of correct sentences than incor-

rect sentences, as indexed by the amplitude of the inversed P600.

Our speculation above is of course very primitive, specifically given that only possible general mechanisms are provided to account for the occurrence of the inversed P600 effect. It is necessary to further investigate and to reevaluate the validity of the postulated mechanisms. Since recent Japanese studies provided evidence for the conventional P600 effect in response to syntactic anomalies (Nakagome, et al., 2001; Oishi & Sakamoto, 2004; Ueno & Kluender, 2003), it is possible that the occurrence of the inversed P600 could be restricted to some specific conditions. The focus in further studies may thus include types of anomalies and sentential conditions as well (e.g., sentence length or the number of phrases, the position of the critical words, and the nature of stimulus sets). Furthermore, the deflections in the P600 range were shown to be dissociable on the basis of their distributions, and such differentiation is still under discussion (Münte, Heinze, Matzke, Wieringa, & Johannes, 1998; Hagoort & Brown, 2000). In the present study, the inversed P600s in Experiments 1 and 2 were also apparently different from each other in size and distribution. A similar issue regarding differentiation is thus still open to question.

In conclusion, the present study showed that the following ERPs would be specifically sensitive to the processing of case-marking constraints in Japanese sentences. Firstly, only under strong top-down influence of anomaly detection and correction, case-marking anomalies caused by "O"-verbs triggered the LAN effect, whereas those by "Ni"-verbs the N400-like effect. Clearly both effects are less automatic and cannot be accounted for by a unitary ERP response to syntactic (subcategorization) violations. Both effects may reflect different processing manners for the same syntactic violations but for different pairs of case particles and verbs. Given the LAN/N400 distinction in the literature, the present LAN (for "O"-verbs) and N400-like (for "Ni"-verbs) effects may reflect morphosyntactic and thematic aspects of the case-verb integration, respectively. Second, in a relatively task-independent manner, case-marking anomalies caused by both "O"- and "Ni"-verbs triggered the inversed P600 effect, that was opposite in direction to the conventional P600 grammaticality effect. The amplitude of this positivity and the effect of anomalies were markedly larger if such strong top-down influence was imposed by the task demands. In our speculative opinion, the effect could reflect

relative acceleration of context-updating processes for correct sentences. The conventional and inversed P600 effects might be modulated by such more general factors that could have a positive or negative correlation to grammaticality depending on sentential conditions.

Acknowledgments

References

Arao, H., Suwazono, S., & Sakamoto, T. (2003). Syntactic aspects of mental lexicon: An analysis of the case-selection characteristics of Japanese transitive verbs using sentence-naturalness ratings, *Studies in Humanities*, 113, 1–13. (In Japanese).

Bobrow, S., & Bower, G. (1969). Comprehension and recall of sentences. *Journal of Experimental Psychology*, 80, 455–461.

Bornkessel, I., McElree, B., Schlesewsky, M., & Friederici, A. (2004). Multi-dimensional contributions to garden path strength: Dissociating phrase structure from case marking. *Journal of Memory and Language*, 51, 495–522.

Clark, H. & Clark, E. (1977). *Psychology and language: An introduction to psycholinguistics*. San Diego, CA: Harcourt Brace Jovanovich Publishers.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, 11, 357–374.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, 6, 78–84.

Frisch, S., & Schlesewsky, M. (2001). The N400 reflects problems of thematic hierarchizing. *Neuroreport: For Rapid Communication of Neuroscience Research*, 12, 3391–3394.

Frisch, S., & Schlesewsky, M. (2005). The resolution of case conflicts from a neurophysiological perspective. *Cognitive Brain Research*, 25, 484–498.

Hagoort, P., & Brown, C.M. (2000). ERP effects of listening to speech compared to reading: The P600/SPS to syntactic violations in spoken sentences and rapid serial visual presentation. *Neuropsychologia*, 38, 1531–1549.

Hagoort, P., Brown, C. M., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an

ERP-measure of syntactic processing, *Language and Cognitive Processes*, 8, 439–483.

Hahne, A., & Friederici, A. (1999). Electrophysiological evidence for two steps in syntactic analysis: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience*, 11, 194–205.

Hahne, A., & Friederici, A. (2002). Differential task effects on semantic and syntactic processes as revealed by ERPs. *Cognitive Brain Research*, 13, 339–356.

Hopf, J., Bayer, J., Bader, M., & Meng, M. (1998). Event-related brain potentials and case information in syntactic ambiguities. *Journal of Cognitive Neuroscience*, 10, 264–280.

Ikehara, S., Miyazaki, M., Shirai, S., Yokoo, A., Nakaiwa, H., Ogura, K., et al. (Eds.). (1997). *Goi-Taikei: A Japanese lexicon*, Tokyo: Iwanami Shoten. (In Japanese).

Inoue, K. (1983). Tanbun-no kouzou, Tokyo: Sanseido In A. Otsuka & K. Inoue (Eds.), *Nihongo-no kihonkozou* (6–13). Tokyo: Sanseido. (In Japanese).

Jasper, H. H. (1958). Report of the committee on methods of clinical examination in electroencephalography. *Electroencephalography and Clinical Neurophysiology*, 10, 370–375.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*, 15, 159–201.

Kaan, E., & Swaab, T. (2003). Electrophysiological evidence for serial sentence processing: A comparison between non-preferred and ungrammatical continuations. *Cognitive Brain Research*, 17, 621–635.

Kuperberg, G. R., Caplan, D., Sitnikova, T., Eddy, M., Holcomb, P. (2006). Neural correlates of processing syntactic, semantic and thematic relationships in sentences. *Language and Cognitive Processes*, 21, 489–530.

Kutas, M., Federmeier, K., Coulson, S., King, J. W., Muente, T. F. (2000). Language. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of Psychophysiology*, 2nd ed. Cambridge University Press.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science*, 207, 203–205.

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition*, 11, 539–550.

Münte, T. F., Heinze, H. J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia*, 36, 217–226.

Münte, T., Matzke, M., & Johannes, S. (1997). Brain activity associated with syntactic incongruencies in words and pseudo-words. *Journal of Cognitive Neuroscience*, 9, 318–329.

Nakagome, K., Takazawa, S., Kanno, O., Hagiwara, H., Nakajima, H., Itoh, K. & Koshida, I. (2001). A topographical study of ERP correlates of semantic and syntactic violations in the Japanese language using the multi-channel EEG system. *Psychophysiology*, 38, 304–315.

Neville, H., Nicol, J., Barss, A., Forster, K., & Garret, M. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*, 3, 151–165.

Oishi, H. & Sakamoto, T. (2004) An ERP study on the timing of the parser's structural decision: Is the parsing performance performed in an incremental manner or in a delayed manner? *Cognitive Studies*, 11, 311–318. (In Japanese).

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97–113.

Osterhout, L. (1997). On the brain response to syntactic anomalies: Manipulations of word position and word class reveal individual differences. *Brain and Language*, 59, 494–522.

Osterhout, L., & Holcomb, P. J. (1992). Event-related potentials elicited by syntactic anomaly. *Journal of Memory and Language*, 31, 785–806.

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20, 786–803.

Takezawa, K. & Whitman, J. (1998). *Kaku-to gojun-to tougokouzou*. Tokyo: Kenkyusha. (In Japanese).

Ueno, M. & Kluender, R. (2003). Event-related brain indices of Japanese scrambling. *Brain and Language*, 86, 243–271.