The Role of Punctuation in Processing Relative-Clause Sentence Constructions in Japanese

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Abstract

In the present study, self-paced reading and event-related potential experiments were conducted to explore the roles commas play in reading complex sentences in Japanese, a language in which punctuation rules are less strictly imposed. The results strongly indicated that commas could immediately activate a complex-sentence structure and affect the processing of the following inputs; however, this activation was suggested to be predominated by a strong bias toward the simplex-sentence interpretations when the following inputs were consistent with the simplex-sentence structures.

Keywords: sentence processing; Japanese; punctuation; event-related potentials; P600; closure positive shift

Introduction

For sentence comprehension, readers or listeners must analyze the sentence structures correctly and quickly. Due to their verb-final sentence structure, Japanese sentences often remain structurally ambiguous until the sentence- or clause-final verb, a fact that seems to make online sentence processing difficult. Previous studies have shown that during reading in various languages, commas effectively disambiguate sentence structures (Hill & Murray, 2000; Steinhauer & Friederici, 2001). However, because Japanese punctuation rules are more permissive than those in many other languages, the role and effect of commas in sentence processing remain unclear.

The main aim of this study was to explore the roles of commas at certain stages of Japanese sentence processing: when the noun phrase (NP) is encountered before the relative-clause (RC) verb, and when the RC verb is encountered in the following RC sentence structures (RCs are put in [ ]; *-ga* is the nominative, *-ni* is the dative, and *-o* is the accusative case marker; the RC verb *otozureta* means "visited," and main verb *syookaisita* means "introduced").

(1) NP1-ga NP2-ni(,) [NP3-o otozureta] NP4-o syookaisita.
"NP1 introduced NP4 who visited NP3 to NP2"

(2) NP1-ga NP2-o(,) [NP3-o otozureta] NP4-ni syookaisita.
"NP1 introduced NP2 to NP4 who visited NP3"

Because Japanese RCs appear without any markers before encountering the RC head (NP4 in [1] and [2]), it is often unclear whether a simplex- or a complex-sentence structure will follow it. In fact, sentences which are identical to (1) until NP3, but end at the first verb, like (3) below, are also possible (*annaisita* means "guided").

(3) NP1-ga NP2-ni NP3-o annaisita.
"NP1 guided NP2 in NP3"

While the main verb *annnaisita* in (3) takes nominative (-*ga*), dative (-*ni*), and accusative (-*o*) case as its argument, the RC verb *otozureta* in (1) does not take the dative case. Therefore, in (1), when encountering the verb *otozureta*, the parser must predict another verb that takes the dative case; that is, a complex-sentence structure is strongly indicated at this point. On the other hand, in (2), both the case of the NP2 and NP3 are accusative. In Japanese, the *Double-o Constraint* (D*o*C: Harada, 1973), which prohibits multiple accusative case markers within a verb phrase (VP), forces the parser to expect that at least two verbs would follow when encountering the NP3 in (2). In fact, Miyamoto (2002), using similar sentences to (1) and (2), demonstrated that more reading time was required on NP3-*o* in condition (2) than (1). Miyamoto claimed that this result indicated that a clause boundary was incrementally established when the NP3 was encountered.

Thus, complex-sentence structure would be strongly indicated at the RC verb (*otozureta*) in (1) and alternatively at the preceding NP (NP3-*o*) in (2). Because the parser's strategy (e.g., Minimal Attachment: Frazier & Fodor, 1978) prefers a simplex-sentence structure, more processing costs would be paid at each point. Our main interest was to see whether these differences in the processing costs would be found even when a comma was inserted at the left clause boundary position.

In Japanese, a possible and recommended position of comma insertion is immediately after NP2-*ni*/-*o* in (1) and (2). It is likely that almost all native speakers read these sentences easier when the comma is present than when it is absent. If the temporary structural ambiguities (simplex vs. complex structure) in (1) and (2) cause the processing difficulties when the comma is absent, one possible explanation is that the comma immediately leads readers to infer the presence of a clause boundary, thus priming a complex-sentence structure in the reader's mind. However, because it is not mandatory in Japanese punctuation rules to insert a comma at this position, the insertion of the comma is entirely dependent on the writer's preferences. Moreover, even in a simplex-sentence structure like (3), comma insertion after the NP2-*ni* is still acceptable.

(4) NP1-ga NP2-ni, NP3-o annaisita.
"NP1 guided NP2 in NP3"

If the comma immediately and strongly indicates a complex-sentence structure, it should be difficult to process (4); however, Japanese writers often insert a comma even in such simplex sentences, and readers may still find this to be natural and feel little difficulty in comprehending the sentence. Therefore, we experimentally investigated whether the comma, when encountered, could really activate a complex structure immediately in Japanese readers, and have also discussed the fact that even simplex sentences accept a comma (in the General Discussion). To our knowledge, no studies have examined this issue.

We used event-related brain potentials (ERP), as well as reading times (RT), to measure the online costs for processing sentences. In the ERP experiment, we focused on the P600 component, which is widely accepted as the component that reflects syntactic analysis costs in language comprehension. As stated above, in RC sentences like (1), more processing costs would occur when encountering RC verb *otozureta*. Alternatively, in (2), more costs would be required when encountering NP3-*o*, but relatively less cost would be required for processing RC verb because the D*o*C would have already made readers establish a complex-sentence structure after processing the preceding NPs. On the other hand, if the comma inserted at the clause boundary could immediately activate a complex-sentence structure, there would be no differences in the amount of processing costs between (1) and (2), both at NP3-*o* and at the RC verb when the comma is present, because the readers no longer have to reanalyze their simplex-sentence structure as a complex one at each point. In this case, it may be expected that the results shown in Table 1 would be obtained for the self-paced reading experiment and the ERP experiment. Conversely, if the comma does not influence the processing of the sentence structure, or influence it later in sentence comprehension (rather than immediately), the difference in the costs between (1) and (2) in NP3-*o* and the RC verb would appear even when the comma is present.

Table 1: Predicted RT and P600 amplitude differences between sentences (1) and (2) as a function of absence or presence of a comma

Comma	NP3-*o*	RC verb
Absent	(1) < (2)	(1) > (2)
Present	(1) = (2)	(1) = (2)

Experiment 1: Self-paced Reading Study

A self-paced reading experiment was conducted to examine whether the comma at the left clause boundary immediately induces the expectation of a complex-sentence structure.

Methods

Participants There were 24 participants (18–23 years old; 8 male, 16 female). All were graduate or undergraduate students in Japan, and were native speakers of Japanese. Both experiments (Experiment 1 and 2) were approved by the ethics committee of the GSIS, Tohoku University.

Materials Sixteen pairs of sentences were prepared; they had the same structure as either (1) or (2) above. Animate nouns were used for NP1, NP2, and NP4; inanimate nouns were used for NP3. All of these sentences consisted of 6 *bunsetsu*. In Japanese, a *bunsetsu* consists of an independent word and optional function words like a case marker. Verbs that take nominative and accusative case, but not dative case, as their arguments were selected as the RC verbs. In addition to these target sentences, 80 filler sentences were also prepared. Fillers included simplex-sentences and different types of RC sentences, with or without a comma.

Design The experiment was a 2 (Comma: absent/present) × 2 (Sentence type: [1] / [2]) repeated measures design. A comma was inserted either at the position of the left clause boundary or not at all. Sentence type was manipulated by changing the case markers of NP2 and NP4 only, as shown in (1) and (2).

Procedure Target sentences were placed in four lists that were counterbalanced for the comma presence and sentence type, using a Latin square design, so that each participant read each sentence only once; therefore, a participant read 16 target and 80 filler sentences in the experiment. The stimuli were displayed *bunsetsu* by *bunsetsu* on the 12.5-in. liquid crystal display of a laptop, in individually randomized order, using the self-paced moving-window paradigm (Just et al., 1982). In the comma-present condition, a comma was presented simultaneously with a punctuated word (i.e., NP2-*ni*/*o*). After having read each sentence, the participants were asked to answer a comprehension question for that trial. The keyboard was used for the self-paced reading and answering of the comprehension questions. The time from the onset of presentation of a *bunsetsu* to the participant's key press (i.e., RT), and responses to the comprehension questions were recorded. Before the experimental session, the participants received brief instructions and completed 8 practice trials.

Results

Following Brown et al. (2012), for RTs of each *bunsetsu*, we conducted statistical analyses using linear mixed-effects models with random intercepts and slopes for participants and items. In the regression models, we included comma presence and sentence type as fixed effects, with interaction between them allowed. The comma-absent and sentence-type (1) conditions were coded as -0.5, and the others were coded as 0.5. In addition, the models also included familiarity of the independent word which a given *bunsetsu* contained (using the database of Amano & Kondo (1999)), the number of characters which a given *bunsetsu* contained, the position of the item in the sequence seen by the subject, and the accuracy of responses to the comprehension questions. Continuous variables were standardized by subtracting the mean value and dividing by the standard deviation. Before statistical analyses, trials including a region in which the reading time was more than 4000 ms or less than 200 ms were excluded from the data.

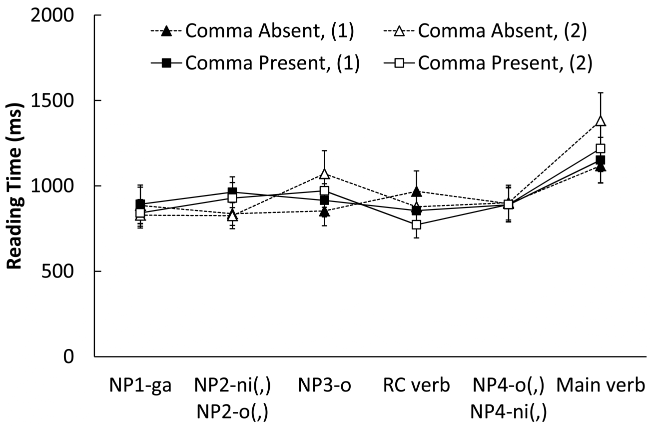

Figure 1: Mean RTs by each region for each experimental condition. Error bars denote 95% confidence intervals.

Table 2: Parameters of the final regression models of RTs for target regions.

	β	*SE*	*t*	
NP3-*o*				
Intercept	1033.61	92.88	11.13	
Comma	-35.83	38.53	-0.93	*ns*
Type	133.47	55.31	2.41	$p < .05$
Comma × Type	-154.54	77.15	-2.00	$p < .05$
RC verb				
Intercept	907.43	81.88	11.08	
Comma	-110.40	59.74	-1.85	$p < .10$
Type	-95.56	41.37	-2.31	$p < .05$
Comma × Type	-16.00	93.11	-0.17	*ns*

Note: Excepting the experimental factors, only the effect of sequential position was significant ($p < .05$) in both regions.

Figure 1 shows the mean RTs by region for each condition, and Table 2 shows the results of statistical analyses for the target regions (NP3-*o* and the RC verb). Importantly, as shown in Table 2, a linear mixed-effects model revealed a significant interaction between comma and sentence type in the third region (NP3-*o*). A follow-up analysis for comma × sentence type interaction revealed that a simple-main effect of sentence type was significant (β = 218.47, *SE* = 81.26, *t* = 2.69, *p* = .01) in the comma-absent condition, but not significant (β = 56.92, *SE* = 50.94, *t* = 1.12, $p > .10$) in the comma-present condition. These results coincide with our prediction (see Table 1), indicating that the comma immediately activates a complex-sentence structure. On the other hand, in the fourth region (RC verb), a significant main effect of sentence type, and a marginally significant effect of comma were found, but no significant interaction between these factors was revealed (see Table 2).

In addition to the target regions, mixed-effects models found a significant main effect of comma in the second region (NP2-*ni*/*o*: β = 108.40, *SE* = 33.47, *t* = 3.24, $p < .01$), and a significant main effect of sentence type in the final region (main verb: β = 155.79, *SE* = 73.71, *t* = 2.11, $p < .05$). No other effects or interactions were significant ($p > .10$).

Discussion

The results of the self-paced reading experiment showed that in the comma-absent condition, the RTs for the third NP (NP3-*o*) in sentence type (2) were clearly longer than in (1), corresponding to the results of Miyamoto (2003). It is plausible that without a comma at the left-clause boundary position, D*o*C forced the readers to reanalyze the simplex-sentence structure as a complex one when encountering the third NP in (2), resulting in the longer RTs (Miyamoto, 2003). However, when a comma was inserted at the clause boundary position, the difference in the RTs for the NP3 between (1) and (2) disappeared. This result is consistent with our prediction, indicating that the comma immediately activates a complex-sentence structure. Readers must have predicted a complex-sentence structure, like an RC sentence structure, when encountering a comma, establishing a clause boundary at the comma's position. Consequently, extra costs were no longer required even when encountering the NP3, which was strongly inconsistent with a simplex-sentence interpretation. The longer RTs in the comma-present condition for the second region (NP2-*ni*/*o*(,)) corresponds to previous eye-tracking experiments (e.g., Hill & Murray, 2000), in which readers focused more on punctuated words. The longer RTs in (2) for the sentence-final verb also correspond to the results of Koizumi and Tamaoka (2004), which indicated that in the ditransitive construction in Japanese, accusative-dative word order is more difficult to process than dative-accusative order.

On the other hand, in the fourth region (RC verb), while the RTs were globally shorter in (2) than in (1) as we expected, no interaction between comma and sentence type was found. Regardless of whether the comma was presented or not, it was more difficult to process the RC verb in (1) than in (2). In Experiment 2, wherein we used ERP, we examined whether the same pattern as in Experiment 1 would occur.

Experiment 2: ERP Study

In Experiment 2, we replicated Experiment 1 using ERP measurements. As stated, we focused on the P600 component, which is widely accepted as the component that reflects syntactic analysis costs.

In addition to P600, we focused on the Closure Positive Shift (CPS) component (Steinhauer et al., 1999), which was confirmed to be elicited by a prosodic break and a comma (Steinhauer & Friederici, 2001). Actually, even in Japanese, a prosodic break was found to elicit CPS (Wolff et al., 2008); however, to our knowledge, there have been no previous studies that investigated the comma-induced CPS in Japanese.

Methods

Participants There were 20 participants (18–26 years old; 11 male, 9 female) who had not participated in Experiment 1; all were right-handed graduate or undergraduate students in Japan and were native speakers of Japanese.

Materials Forty pairs of target sentences and 160 fillers were prepared in the same manner as in Experiment 1.

Design The same design as Experiment 1 was used.

Procedure Each target sentence was modified to make four different experimental conditions according to the presence of the comma and sentence types ([1] or [2]). All of these four sentences were shown to each participant; thus, a participant read 160 target and 160 filler sentences during the experiment. The stimuli were presented *bunsetsu* by *bunsetsu* on the center of a 17-in. CRT display in an individually pseudo-randomized order, one *bunsetsu* at a time with 650 ms duration and 1100 ms stimulus onset asynchrony between *bunsetsu*'s. In the comma-present condition, a comma was presented on the same screen as a punctuated word. In each trial, instead of the presentation of the sentence-final word, two alternative words were presented simultaneously; one of them was suitable as a sentence-final word, and the other was syntactically or semantically incorrect as the sentence-final word. Participants were required to choose the correct word in each trial. When they made an incorrect choice, the data of the trials were excluded from the analyses. Before the experimental session, the participants received brief instructions and completed 10 practice trials.

EEG Recordings and Analysis Continuous EEG was recorded (1000 Hz sampling rate; Brain Products BrainAmp DC amplifier) from 19 cap-mounted Ag/AgCl electrodes (Easy Cap) placed according to the standard International 10-20 System, and two earlobe electrodes, as well as electrodes placed below the left eye and at the outer canthus of each eye for EOG monitoring. An electrode located halfway between Fpz and Fz served as the ground. All electrodes were referenced against the left earlobe; reference was re-calculated to the average of the activities at the two earlobes. Electrode impedances were kept below 5 kΩ.

Single-participant averages were computed separately for each experimental condition after filtering (0.16–30Hz bandpass), segmentation, baseline correction, and artifact rejection. EEG and EOG recordings were examined during the epochs from 100 ms preceding the onset of each *bunsetsu* until 1000 ms after the respective onset. We used a 100-ms period preceding the onset of the *bunsetsu* as a baseline. Only trials in which the EOG did not exceed 50 µV, and in which no artifacts (EEG > 100 µV) occurred, were included in the analyses. The data from four participants (2 male, 2 female) were excluded from the analyses due to excessive artifacts.

Based on a previous study (Kerkhofs et al., 2007), a 400- to 800-ms time-window after the onset of the second *bunsetsu* (NP2-*ni*/*o*(,)) was used to quantify a CPS at the comma; a 600- to 900-ms time-window after the onset of the third *bunsetsu* (NP3-*o*) and fourth *bunsetsu* (RC verb) was used to quantify a P600 effect. The mean amplitudes of these windows were entered into ANOVA repeated-measures analyses. The ANOVAs included four within-group factors (two experimental factors and topographical factors): comma (absent/present), sentence type ([1]/[2]), anterior/posterior (frontal/central/posterior), and laterality (left-lateral/left-medial/midline/right-medial/right-lateral) [1]. Greenhouse-Geisser corrections were used where applicable.

Results

CPS in NP2-*ni*/*o*(,) Figure 2 shows the grand average waveforms (Fz, Cz, and Pz) time-locked to the onset of the presentation of the second region (NP2-*ni*/*o*(,)).Visual inspection of the waveforms suggests that the presence of a comma gives rise to a CPS, particularly at the posterior sites. An ANOVA examining the mean amplitudes of the CPS time-window found a significant main effect of comma ($F(1,15) = 5.66$, $p < .05$) and an interaction between comma and anterior/posterior ($F(0.92,27.52) = 6.03$, $p < .05$). A follow-up analysis of the comma × anterior/posterior interaction showed significant simple-main effects of comma at central ($F(1,15) = 5.37$, $p < .05$) and posterior ($F(1,15) = 4.96$, $p < .05$) sites. A marginally significant interaction between comma and laterality was found ($F(1.80,27.00) = 2.72$, $p < .10$). No other effects or interactions regarding the experimental factors were significant ($p > .10$).

From these results, we concluded that the CPS was elicited by the presence of the comma.

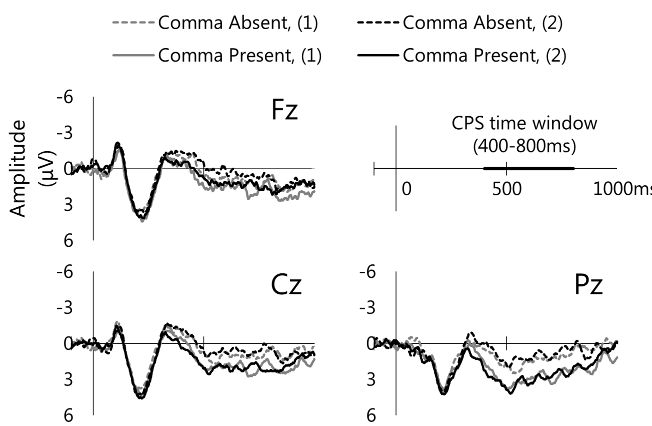

Figure 2: Grand average waveforms time-locked to the onset of NP2-*ni*/*o*(,) for each experimental condition.

P600 in NP3-*o* Figure 3 shows the grand average waveforms time-locked to the onset of the presentation of the third region (NP3-*o*) for the comma-absent condition, while Figure 4 shows the same information for the comma-present condition. Visual inspection suggests that a posterior-distributed P600-like effect was found in (2) than (1) in the comma-absent condition, but not in the comma-present condition. An ANOVA examining the mean amplitude of the 600–900-ms time-window found a significant main effect of sentence type ($F(1,15) = 4.83$, $p < .05$), and significant interactions between comma and

[1] In the present study, to simplify analyses, the data from the four electrodes (Fp1/2, O1/2) were not entered into ANOVAs.

sentence type ($F(2.11,31.72) = 4.08$, $p < .05$) and between comma, sentence type, and anterior/posterior ($F(1.15,17.19) = 5.78$, $p < .05$). A follow-up analysis of the comma × sentence type × anterior/posterior interaction revealed that a simple-interaction between comma and sentence type was significant only at the posterior site ($F(1,15) = 6.43$, $p < .05$). For this simple-interaction, a simple-simple-main effect of sentence type was significant in the comma-absent condition ($F(1,15) = 7.55$, $p < .01$), but not in the comma-present condition ($F(1,15) = 0.02$, $p > .10$). No other effects or interactions regarding the experimental factors were significant ($p > .10$).

From these results, we concluded that in the comma-absent condition, the presentation of the third NP (NP3-*o*) in (2) resulted in a larger P600 effect than in (1), while in the comma-present condition the presentation of the third NP did not result in the P600 effect.

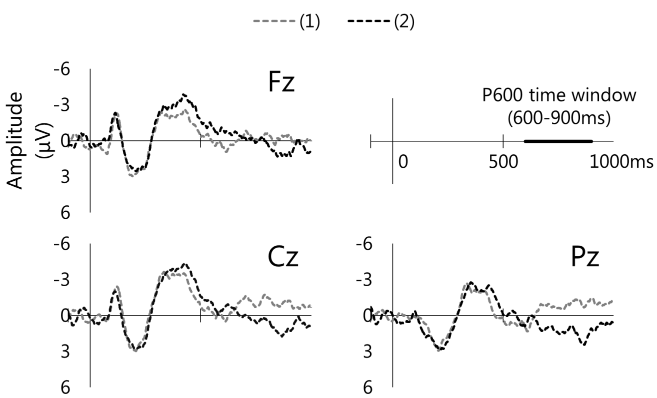

Figure 3: Grand average waveforms time-locked to the onset of NP3-*o* for each sentence-type condition in the comma-absent condition.

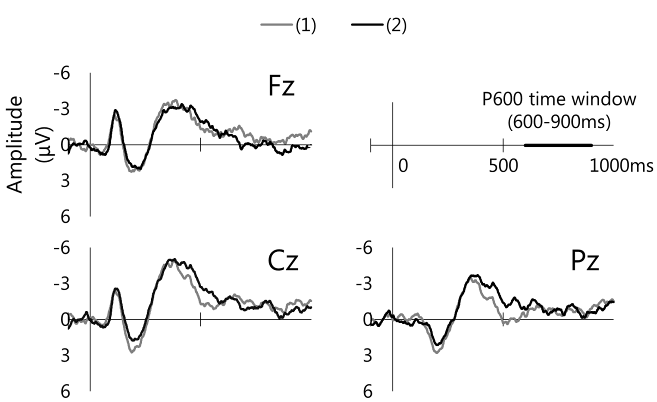

Figure 4: Grand average waveforms time-locked to the onset of NP3-*o* for each sentence-type condition in the comma-present condition.

P600 in RC Verb Figure 5 shows the grand average waveforms time-locked to the onset of the presentation of the fourth region (RC verb). Visual inspection suggests that a larger posterior-distributed P600-like effect was found in (1) than (2). An ANOVA examining the mean amplitude of the 600–900-ms time-window found a significant main effect of sentence type ($F(1,15) = 17.39$, $p < .01$) and an interaction between sentence type and anterior/posterior ($F(1.23,18.39) = 5.19$, $p < .05$). A follow-up analysis for the sentence type × anterior/posterior interaction revealed that simple-main effects of sentence type were significant at each level of the anterior/posterior site (frontal: $F(1,15) = 8.09$, $p < .05$; central: $F(1,15) = 16.55$, $p < .01$; posterior: $F(1,15) = 17.36$, $p < .01$). In addition, an interaction between comma and sentence type was marginally significant ($F(1,15) = 3.79$, $p < .10$). However, a follow-up analysis of the comma × sentence type interaction revealed that simple-main effects of sentence type were significant both in the comma-absent ($F(1,15) = 16.17$, $p < .01$) and comma-present ($F(1,15) = 7.44$, $p < .05$) conditions. No other effects or interactions regarding the experimental factors were significant ($p > .10$).

From these results, we conclude that the presentation of the RC verb in (1) resulted in a larger P600 effect than in (2), but presence or absence of a comma did not influence this difference.

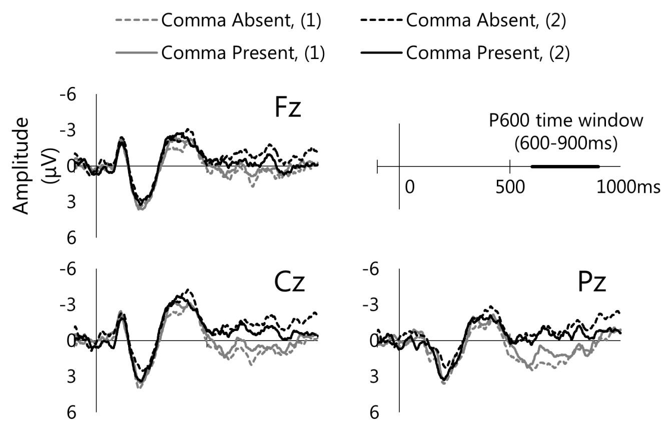

Figure 5: Grand average waveforms time-locked to the onset of the RC verb for each experimental condition.

Discussion

Replicating the behavioral results of Experiment 1, a larger P600 effect was found in (2) than in (1) at the third NP (NP3-*o*) in the comma-absent condition, and this effect disappeared in the comma-present condition. If the larger P600 is interpreted as a reflection of additional processing load accompanying the reanalysis of the simplex-sentence structure into a complex one, these results physiologically support the view of Miyamoto (2002). Miyamoto claimed that in Japanese, clause boundaries could be incrementally established using the cues of the case markers even before encountering a verb. Moreover, it is likely that because the comma can immediately establish a clause boundary and activate a complex-sentence structure, there was no processing difficulty for the third NP in (2) relative to that in (1), when a comma was present at the clause boundary position. In addition, this is the first evidence in Japanese that indicates CPS effects being elicited by the presence of a comma. The comma-induced CPS was found in German sentences (Steinhauer & Friederici, 2001) but not in Dutch sentences (Kerkhofs et al., 2008). *Why* the comma-induced CPS was found in the present study (in Japanese) is a very important question; however, because it is not the main focus here, we do not pursue this topic further. It should be noted, however, that the CPS in the present study provides indirect support for the view that the comma, when it occurs in Japanese, immediately affects sentence processing.

Surprisingly, the results regarding the RC verb were very similar to that of Experiment 1. A larger P600 effect was elicited in (1) than in (2), and the comma presence did not influence this effect. We discuss this point at the end of the General Discussion.

General Discussion

Based on the results of the two experiments presented here, we strongly suggest that commas in Japanese can immediately activate a complex-sentence structure in the reader's mind and affect sentence parsing before a verb is encountered. Miyamoto (2002) claimed that even before a verb, sentence structures could be constructed using the cues of the case markers. Our results are in agreement with his suggestion. Moreover, punctuation cues can also be utilized in the early stages of Japanese sentence processing, although punctuation rules are much more permissive. However, the nature of the rule use being less strict suggests that the commas in Japanese play various other roles, in addition to inducing clause boundaries. Further studies are needed to examine the roles played by the commas more thoroughly.

Finally, we discuss a possible reason why the comma does not seem to affect processing of the RC verb in either of the two experiments. If commas activate a complex-sentence structure immediately, the difference in costs between (1) and (2) for processing the RC verb should disappear when the comma is present. There are two possible interpretations for this. First, in sentence type (1), participants simply ignored the comma. This is not, however, a plausible interpretation because the comma-induced longer RTs and larger CPS effects in the punctuated word were found in (1) exactly as in (2), implying similar attention to the comma between conditions. An alternative and more plausible explanation is that a strong bias to the simplex-sentence structure was implicitly still viable even when the comma was present.

A possible processing model of the present stimuli is that when encountering a comma, a reader assumed a complex-sentence structure. If the next input (NP3-*o*) is inconsistent with a complex structure (i.e., sentence type (2)), processing continues while retaining a complex-sentence interpretation. On the other hand, when the input (NP3-*o*) is consistent with a simplex structure (i.e., sentence type (1)), a strong bias to a simplex structure predominates over the activation of a complex structure even with the comma. Consequently, when encountering an RC verb, which is inconsistent with a simplex structure, reanalysis costs are required even when a comma is presented. This possibility is also consistent with the fact that a simplex sentence with the comma (i.e. [4]) seems to show no increased load on processing. However, this model has additional factors to consider. For example, how strong is the bias toward the simplex structure? Does it require no processing costs to change a complex-sentence interpretation to a simplex one? Additional investigation is necessary to clarify these points and further explore the role of punctuation in Japanese.

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