Revision Process in Japanese Sentence Processing: Evidence from Event-Related Brain Potentials

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1. Introduction

A large number of studies on human sentence processing have been devoted to the investigation of how the sentence processor resolves temporary ambiguity that emerged during the initial processing. Some recent studies, however, have stressed the importance of investigating the processor's behavior during reanalysis; for example, how the processor behaves when there are two or more revision paths available to the processor (Frazier & Clifton, 1998; Sturt & Crocker, 1996; Sturt et al., 2002, and references therein).

Frazier & Clifton (1998), for example, introduced the *Minimal Revisions Principle*, which requires the processor to retain as much of the existing structure and interpretation as possible. Similarly, Sturt & Crocker (1996) claimed that the processor has a tendency to preserve the maximum number of structural dependencies established during the initial processing and proposed the *Tree-lowering* as a principle governing revision processes. Each of these studies demonstrated that their respective principles can accurately explain the processor's preference in reanalysis, which is originally reported in Mazuka & Itoh (1995). Mazuka & Itoh contrasted the processing difficulties between two types of Japanese relative-clauses. As Japanese is a head-final language, the relative clause always precedes the head noun it

modifies. Furthermore, the processor does not recognize that the incoming sentence involves a relative clause until the appearance of the head noun since Japanese does not have any overt constituents which cue the onset of relative clause. Therefore, the processor would construct a simple clause as in (1b) when the first verb *mikaketa* 'saw' in (1a) is encountered. When the head noun of the relative clause (*onnanoko-ni*, 'girl-DAT') is encountered, however, the processor has to revise the existing structure and construct a relative clause in order to attach the head noun. In some cases, an empty category which is coindexed with the head noun should be posited in the subject position of relative clause as in (1c). In other cases, the processor must posit two empty categories as in (2b); one is coindexed with the subject of the matrix clause and the other, the head noun of the relative clause.

(1)a. Yoko-ga   kodomo-o koosaten-de mikaketa onnanoko-ni koe-o kaketa.
    name-NOM   child-ACC   intersection-LOC saw   girl-DAT   called
    'Yoko called the girl who saw the child at the intersection.'

  b. [$_S$ *Yoko-ga*   *kodomo-o*   *koosaten-de*   *mikaketa*]
      name-NOM   child-ACC   intersection-LOC   saw
    'Yoko called the girl at the intersection.'

  c. [$_S$ *Yoko-ga* [$_{NP}$[$_S$ *ec$_i$ kodomo-o koosaten-de mikaketa*] *onnanoko$_i$-ni*] *koe-o kaketa*]
                                                  (*adapted from Mazuka & Itoh, 1995*)

(2)a. *Yoko-ga*   *kodomo-o*   *kousaten-de*   *mikaketa*   *onnanoko-ni*   *azuketa.*
    name-NOM   child-ACC   intersection-LOC saw   girl-DAT   entrusted
    'Yoko entrusted the child to the girl whom she saw at the intersection.'

  b. [$_S$ *Yoko$_i$-ga   kodomo-o* [$_{NP}$[$_S$ *ec$_i$ ec$_j$ koosaten-de   mikaketa*] *onnanoko$_j$-ni*] *azuketa*]
                                                                              (*ibid.*)

Mazuka & Itoh argued that the revision process in (2) is more difficult than that in (1) following their intuitions, suggesting that positing two empty categories at

the appearance of the head noun is more costly than positing one empty category. Frazier & Clifton and Sturt & Crocker each claimed that their own principles can correctly predict the processing difficulty in (2) because positing one empty category results in the structure which preserves more of the existing structure (or more numbers of structural dependencies) than does positing two empty categories.

Hirose & Inoue (1998), however, argued that positing two empty categories is not necessarily difficult when the head noun is thematically unambiguous. They contrasted reading times for thematically-ambiguous head nouns with reading times for thematically-unambiguous head nouns. The former was reliably longer than the latter, even though the sentence processor only had to posit one empty category at the appearance of thematically-ambiguous head nouns. Hirose & Inoue concluded that the thematic processing precedes the syntactic processing during reanalysis and the temporary ambiguity resulting from the thematic ambiguity of the head noun makes reanalysis more difficult.

Although the results reported in Hirose & Inoue suggest that the processor is willing to destroy the existing structural relations when ambiguities do not emerge during reanalysis, they do not rule out the possibility that the processor will maintain as much of the existing structure as possible when there are two or more revision paths. If this is the case, however, the processor has to activate all the possible structures and choose the least destructive one among them. Such a process must be very costly. We instead introduce an alternative principle which explicitly tells the processor how to make a revision without caring about preserving the existing structure.

2. The Principle

As mentioned above, trying to retain as much existing structural relations as possible in reconstructing the existing structure seems to be very laborious. Thus, we present an alternative principle that governs revision processes:

(3)   *Error Signal-based Revisions Principle (ESRP)*
      When an error signal is encountered, construct "the minimum maximal-pro-
      jection" that has the fewest number of nodes among those which can domi-
      nate the error signal and be incorporated into the existing structure. Fill each
      argument position in the minimum maximal-projection with an overt ele-
      ment if possible.

We illustrate how the processor with the ESRP works with the examples shown
above. When the error signal *onnanoko-ni* 'the girl' is encountered, the ESRP or-
ders the processor to construct the noun phrase headed by the error signal con-
taining a relative clause because it is "the minimum maximal-projection" (see (3)
for its definition). Furthermore, since the ESRP requires the processor to fill the
argument positions in the minimum maximal-projection with overt elements, the
processor reanalyzes *kodomo-o* 'the child' as the object of the relative-clause verb
(the subject position of the relative clause must be an empty category coindexed
with the head noun). Therefore, the ESRP can predict that the revision process as
in (2) is not preferred. In what follows, we give more illustration about the Error
Signal-based Revisions Principle by showing how it works with the sentences
used in the subsequent experiment.

      In this study, we directly contrasted predictions stemming from the ESRP and
the principles that emphasize maintaining of the existing structure ("structure-
preserving principles", hereafter) in order to investigate which one is more valid as
an ambiguity-resolution principle.

(4)a.   [$_{IP}$ *Daijin-ga*   [$_{VP}$ *honbu-ni*   [$_{NP}$[$_{IP}$ *ec_i atsumatta*]   *uragane$_i$-o*]   <u>*azuketa*</u>]].
        minister-NOM   the headquarters-DAT   was donated   secret money-ACC   entrusted
        'A minister entrusted the secret money donated to him to the headquarters.'

  b.   [$_{IP}$ *Daijin-ga* [$_{NP}$[$_{IP}$ *ec_i honbu-ni*   *atsumatta*]   *uragane$_i$-o*]   <u>*nusunda*</u>]].
        minister-NOM   to the headquarters   was donated   secret money-ACC   stole
        'A minister stole the secret money donated to the headquarters.'

(4a) is identical with (4b) up to the matrix verb: the matrix verb of (4a) is a ditran-

sitive verb *azuketa* 'entrusted'. On the other hand, (4b) contains a transitive verb *nusunda* 'stole'. Note that the syntactic role of the second NP (i.e., *honbu-ni* 'to the headquarters') varies along with the argument-taking property of each matrix verb. In (4a), the second NP is interpreted as an argument of the matrix verb and as the location to which the secret money was entrusted. In (4b), on the other hand, the second NP cannot be the argument in the matrix clause because the matrix verb is a transitive verb, and therefore does not take any dative-marked NP. Therefore, the second NP cannot be interpreted as the location where the secret money was entrusted. Instead, it is interpreted as the location where the secret money was donated.

We now demonstrate how the processor with the ESRP deals with these sentences. We assume that the initial processing is performed in an incremental manner following the suggestions from theoretical studies (Inoue & Fodor, 1995) and experimental studies (Kamide & Mitchell, 1999; Oishi & Sakamoto, 2004). It is generally assumed that the processor tries to make the simplest structure in the initial analysis (e.g., *Minimal Attachment* in Frazier & Fodor (1978)) at least when there is no explicit information which prompts the processor to take another analysis (e.g., Trueswell, Tanenhaus, & Garnsey, 1994). Such a processor will construct a simple clause when the first verb *atsumatta* is encountered. Note that *honbu-ni* is attached as an adjunct of the matrix clause at this point.

(5)   [$_{IP}$ *daijin-ga*   [$_{VP}$ *honbu-ni*   *atsumatta*]]
         minister-NOM   the headquarter-LOC   gathered
      'Ministers gathered at the headquarters.'

At the appearance of the next input, however, the processor recognizes that the simple clause analysis has to be abandoned because it cannot incorporate *uragane-o* 'secret money-ACC' without revising the current structure. The ESRP requires the processor to construct the noun phrase headed by the error signal which contains a relative clause that is the minimum maximal-projection. We, however, should notice that there are two possible ways for constructing such an NP, as shown in (6).

(6)a. $[_{IP}$ *daijin-ga* $[_{VP}$ $[_{NP}$ $[_{IP}$ *ec*$_i$ $[_{VP}$ *honbu-ni atsumatta*$]]$ *uragane*$_i$-*o*$]$ ...

   b. $[_{IP}$ *daijin-ga* $[_{VP}$ *honbu-ni* $[_{NP}$ $[_{IP}$ *ec*$_i$ $[_{VP}$ *atsumatta*$]]$ *uragane*$_i$-*o*$]$ ...

The ESRP requires the processor to construct the structure shown in (6b) because the error signal and the relative-clause verb will suffice for constructing the minimum maximal-projection. Here, the structure-preserving principles would prefer (6a) to (6b) because the structural dependency between the adjunct NP and the relative-clause verb in the existing structure is preserved in (6a). Hence, according to the ESRP, *honbu-ni* is assumed to remain in the matrix clause (i.e., (6b)), contrary to the structure-preserving principles which predict that the NP would be a clause mate of the verb *atsumatta* (i.e., (6a)).

   When a ditransitive verb like *azuketa* 'entrusted' is subsequently encountered, the processor notices that the indirect object of the verb (a dative-marked NP) is missing in the current structure. If the processor obeys the ESRP, it will reanalyze the adjunct NP in the matrix clause as the argument of the matrix verb because the ESRP requires it to fill the argument position with the overt element if possible. According to the structure-preserving principles, the processor would posit an empty category in the argument position because it is the best way to preserve the existing structure.

   In the case of a transitive verb like *nusunda* 'stole', the processor with the ESRP faces a problem of how to deal with the adjunct NP in the matrix clause. The adjunct NP *honbu-ni* cannot modify the matrix verb *nusunda* because it denotes a kind of place. Therefore, the sentence cannot be acceptable unless the adjunct NP is reanalyzed as a constituent of the relative clause. Thus, the processor has to reattach the adjunct NP into the relative clause. According to the structure-preserving principles, by contrast, no problem would arise when *nusunda* is encountered because the argument structure of the verb matches the current structure.

   To sum up, the ESRP predicts that revision processes will be triggered by both types of matrix verbs. The structure-preserving principles, on the other hand, would predict that intransitive verbs will trigger the revision process. We should note that the ESRP cannot assess the amount of cost required for a revision process since it just tells the processor how to perform the revision process. However,

according to the ESRP, the reanalysis triggered by transitive verbs is assumed to be more difficult than that triggered by ditransitive verbs because the former involves structural changes, while such structural changes are not necessary for the latter.

3. Experiment

To examine which one is appropriate as an ambiguity-resolution principle for the sentence processor's revision process, we recorded event-related brain potentials (ERPs) while the participants silently read the sentences. One well-established ERP effect that has been found to be related to revision processes is known as the P600, or Syntactic Positive Shift (hereafter, P600/SPS). The P600/SPS is a positive component starting at about 400–500ms subsequent to the onset of the target word. The P600/SPS has been observed in response to various types of ungrammatical or nonpreferred continuations (Friederici, Hahne, & Saddy, 2002; Hagoort & Brown, 2000; Hagoort, Brown, & Groothusen, 1993; Kaan & Swaab, 2003; Oishi & Sakamoto, 2004; Osterhout & Holcomb, 1992; among others), and syntactic integration difficulty resulting from the establishment of filler-gap dependencies (*WH*-movement: Fiebach, Schlesewsky, & Friederici, 2002; Kaan, Harris, Gibson, & Holcomb, 2000, NP-movement via *scrambling*: Ueno & Kluender, 2003). Furthermore, the amplitude of the P600/SPS is found to be the function of the reanalysis cost (Osterhout, Holcomb, & Swinney, 1994).

As mentioned above, according to the ESRP, it is predicted that the processing cost associated with reanalysis in the case of transitive verbs is relatively higher than that in the case of intransitive verbs. Therefore, the amplitude of the P600/SPS would be larger in the transitive-verb condition than that in the ditransitive-verb condition. By contrast, in line with the structure-preserving principles, it is predicted that the P600/SPS effect will be observed in the ditransitive-verb condition, since such principles predict that revision processes will be triggered when ditransitive verbs are encountered.

Methods

Participants

20 right-handed participants (15 female) participated in the experiment for payment and/or course credit. All were Japanese native speakers, monolingual, and undergraduate students of Kyushu University. All had normal or corrected-to-normal vision.

Material

Experimental sentences consisted of two conditions: the ditransitive-verb condition (=(4a)) and the transitive-verb condition (=(4b)), as illustrated in Table 1 below. 120 sets of such pairs were constructed. The experimental sentences were distributed according to a Latin square design, creating four parallel lists such that no one participant saw more than one sentence from each set. Each list contained 30 sentences of each condition. 210 filler sentences which consisted of various types of sentences were added to each list, creating 240 items in total for each list. Each list was then pseudo-randomized and divided into eight blocks of 30 items, with each block containing each type of experimental and filler sentences.

Procedure

Participants were seated in front of a computer screen in a comfortable chair in a dim, sound-attenuated booth. At the beginning of the experiment, the distance from the screen was adjusted to the participants' comfort. Sentences were visually presented at the center of the screen in a *bunsetsu*-by-*bunsetsu* manner. A *bunsetsu* consists of a lexical item, or a lexical item with a particle (e.g., *daijin ga*). Each *bunsetsu* was presented with 600ms duration, with the next *bunsetsu* being present-

Table 1. *Example of sentence types constructed from one pair with literal English translation (underlying indicates disambiguating element).*

ditransitive-verb condition (=(4a))	*daijin-ga honbu-ni atsumatta uragane-o <u>azuketa</u>.*
	A minister entrusted the secret money donated to him to the headquarters.
transitive-verb condition (=(4b))	*daijin-ga honbu-ni atsumatta uragane-o <u>nusunda</u>.*
	A minister stole the secret money donated to the headquarters.

ed 100ms after the offset of the previous one (SOA: 700ms, ISI: 100ms). A period was presented for 600ms to signal that one trial was over. 2000ms after the offset of a period, a probe word was presented, and the participants were asked to judge whether it was contained in the sentence just presented and respond by pressing one of two buttons. The next trial then began 3000ms after the response with a fixation point that was presented for 3000ms, and 700ms later the first word of the next sentence was presented. Participants were instructed not to blink or move their eyes while the sentential stimuli were being presented.

EEG Recording

EEG was recorded from seven Ag-AgCl electrodes located at Fz, Cz, Pz (midline), and F3, F4, P3, and P4 (parasagittal) according to the International 10–20 system (Jasper, 1958). The vertical EOG and blinks were monitored by means of an electrode placed beneath the left eye. EEG was referenced to electrodes placed on both earlobes and amplified with a band-pass of 0.01 to 100Hz. Electrode impedance was kept below 5kΩ. The sampling rate was 200Hz.

Data Analysis

ERPs were quantified as the mean voltage relative to 100ms prestimulus baseline preceding matrix verbs, using the 300–500ms, 500–800ms and the 800–1100ms time window. These time windows were selected based on the visual inspection and literature. Less than 5 % of the data were rejected per condition due to excessive eye movements or amplifier blocking (EOG-rejection criterion: ±40μV within 100ms preceding and 1000ms following presentation of matrix verbs). Repeated measures ANOVAs were conducted separately for midline and parasagittal with within-participants factors to allow for quantification of hemispheric differences. Two-way ANOVAs treating Sentence Type and Electrode Position (frontal, central, and parietal) as factors were conducted on midline data. On parasagittal data, three-way ANOVAs treating Sentence Type, two levels of Electrode Position (frontal/parietal), and two levels of Hemisphere (left/right) as factors were conducted. The Greenhouse-Geisser correction was applied for all effects involving more than 1 degree of freedom (Greenhouse & Geiser, 1959). This was to avoid Type 1 error due to violations of the sphericity assumption of equal variances of
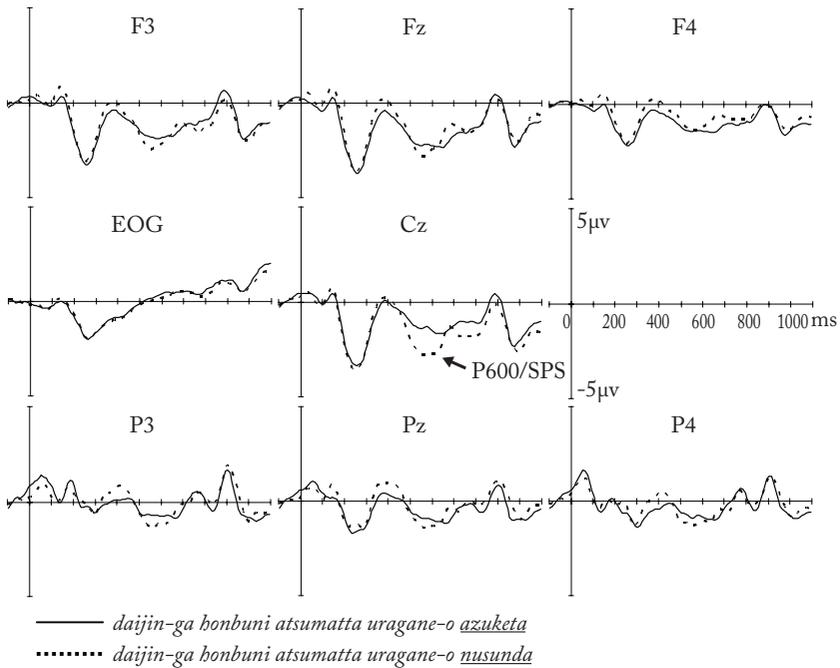
Figure 1. *Grand Average ERPs from seven electrode sites elicited by the matrix verbs of the ditransitive and transitive-verb condition (N=20). ERPs to ditransitive verbs are plotted in solid line, and those to transitive verbs are plotted in dotted line. Negativity is plotted up.*

differences between conditions of within-subject variables.

Results

Figure 1 shows the grand average ERPs elicited by matrix verbs in each sentence type. Visual inspection of Figure 1 suggested that ERPs to the transitive-verb condition showed a positive-going shift at Cz in the 500–800ms time window, relative to those to the ditransitive-verb condition.

In the 300–500ms time window, no significant main effect or interaction was observed. ANOVAs on mean amplitudes at midline sites in the 500–800ms window revealed that the interaction between Sentence Type and Electrode Position was significant [F(2, 38)=3.473, p<.05], indicating that ERPs to the transitive-verb condition was significantly more positive than those to the ditransitive-verb condition at Cz. Analyses on the data in the 800–1100ms time window revealed no significant effects [all ps > .10].

4. Discussion

The aim of the present study was to investigate how the sentence processor would resolve temporary ambiguities in reanalysis. The previous studies which inquired into this issue suggested that the processor would prefer preserving as much of the existing structure as possible. We argued that the principles based on this idea need to be refined because insisting to retain the existing structure as much as possible might be laborious while incorporating the error signal. Therefore, we hypothesized that the processor would resolve temporary ambiguities in reanalysis by following the Error Signal-based Revisions Principle, which requires the processor to construct the minimum maximal-projection for incorporating the error signal into the existing structure. Then we conducted an experiment designed to contrast the predictions stemming from the ESRP and structure-preserving principles concerning which path the processor would take at the ambiguous point. We recorded ERPs while participants read sentences like (4a, b) (repeated again here for the reader's comprehension).

(7)a. $[_{IP}$ *Daijin-ga* $[_{VP}$ *honbu-ni* $[_{NP}[_{IP}$ *ec*$_i$ *atsumatta*] *uragane*$_i$*-o*]   *azuketa*]].
    minister-NOM   the headquarters-DAT   was donated   secret money-ACC   entrusted
    'A minister entrusted the secret money donated to him to the headquarters.'

   b. $[_{IP}$ *Daijin-ga* $[_{NP}[_{IP}$ *ec*$_i$ *honbu-ni*   *atsumatta*] *uragane*$_i$*-o*]   *nusunda*]].
    minister-NOM   to the headquarters   was donated   secret money-ACC   stole
    'A minister stole the secret money donated to the headquarters.'

   The comparison between ERPs to the transitive verbs and those to the ditransitive verbs revealed that the former was significantly more positive within 500-800ms window at Cz in comparison to the latter, indicating that the transitive verbs elicited the P600/SPS, which is an index of the processing difficulty associated with revision process. This suggests that the processor was forced to make a revision when a transitive verb was encountered since it has made a wrong analysis when the head noun was encountered. The fact that the transitive verbs triggered the revision process is consistent with the prediction of the ESRP but con-

tradicts the prediction based on the structure-preserving principles because they assume that the processor will face no problem when a transitive verb is encountered. Therefore, the results of the present study suggest that the principles that emphasize preservation of the existing structural relations would be empirically inappropriate and that the ESRP can hold as an ambiguity-resolution principle for revision processes.

As mentioned above, the ESRP was supported by the finding that the P600/SPS was observed in the transitive-verb condition. According to the ESRP, however, when a ditransitive verb is encountered, the processor has to reanalyze the dative-marked NP (e.g., *honbu-ni*) which was previously analyzed as an adjunct in the matrix clause as an argument of the matrix verb. If this is the case, we can speculate that the ditransitive verbs might also have elicited the P600/SPS, of which scalp distribution is different from that of the P600/SPS effect observed in the transitive-verb condition. The difference between the ditransitive and the transitive-verb condition with regard to the revision process is whether any structural changes are involved. As mentioned above, no structural change is required in the ditransitive-verb condition. On the other hand, the revision process in the transitive-verb condition involves structural changes. These lead us to speculate that the P600/SPS effect reflecting the revision processes involving structural changes might have a wider distribution than that reflecting the revision processes with no structural changes. Though the present study by itself cannot verify this possibility, detailed researches on this possibility will let us know more about the P600/SPS effect as an index of revision process.

5. Concluding Remarks

We have seen that the Error Signal-based Revisions Principle presented here can accurately explain the sentence processor's behavior in the face of temporary ambiguity in reanalysis. Furthermore, it is noteworthy that the basic idea of the ESRP is quite similar to that of the Minimal Attachment Principle, which guides the initial processing; both principles assume that the word under consideration should be incorporated into the existing structure with the fewest number of

nodes. Therefore, the present study suggests that the processor would prefer constructing the simplest structure when temporary ambiguity emerges in the initial analysis as well as in reanalysis. However, as is well-known, a number of studies have shown that the processor does not always obey such a structural principle as Minimal Attachment but makes use of non-syntactic information such as frequency and plausibility in the early stage of initial analysis (e.g., Trueswell, Tanenhaus, & Garnsey, 1994). This leads us to speculate that the processor would employ non-syntactic information in reanalysis as well. Hence, in our lab, we are trying to figure out what kind of non-syntactic information does the processor apply in reanalysis and how the analyses stemming from structural principles such as the ESRP and non-syntactic information interact. Such detailed researches on the revision process will help us understand human language processing.

Acknowledgements

References

Fiebach, C. J., Schlesewsky, M. & Friederici, A. D. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: the processing of German WH-questions. *Journal of Memory and Language*, 47, 250–272.

Fodor, J. D. & Inoue, A. (1994). The diagnosis and cure of garden paths. *Journal of Psycholinguistic Research*, 23, 407–434.

Fodor, J. D. & Inoue, A. (1998). Attach anyway. In J. D. Fodor and F. Ferreira (Eds.), *Reanalysis in Sentence Processing* (101–141). Dortrecht: Kluwer Academic Publisher.

Frazier, L & Clifton, C. (1998). Sentence Reanalysis, and Visibility. In J. D. Fodor & F. Ferreira (Eds.), *Reanalysis in Sentence Processing* (143–176). Dortrecht: Kluwer Academic Publisher.

Frazier, L. & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, 6, 1–34.

Friederici, A. D., Hahne, A., & Saddy, D. (2002). Distinct neurophysiological patterns reflecting

aspects of syntactic complexity and syntactic repair. *Journal of Psycholinguistic Research*, 31, 45–63.

Hagoort, P. & Brown, C. M. (2000). ERP effects of listening to speech compared to reading: the P600/SPS to syntactic violation 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.

Hagoort, P., Brown, C. M., & Osterhout, L. (1999). The neurocognition of syntactic processing. In P. Hagoort & C. M. Brown (Eds.) *The Neurocognition of Language* (273–316). Oxford UK: Oxford University Press.

Hirose, Y. & Inoue, A. (1998). Ambiguity of Reanalysis in Parsing Complex Sentences in Japanese. *Syntax and Semantics*, 31. 71–93.

Inoue, A. and Fodor, J. D. (1995). Information-paced parsing of Japanese. In R. Mazuka and N. Nagai (Eds.), *Japanese sentence processing* (9–63). Hillsdale, NJ: Lawrence Erlbaum.

Kaan, E. & Swaab, T. Y. (2003). Repair, revision, and complexity in syntactic analysis: an electrophysiological differentiation. *Journal of Cognitive Neuroscience*, 15(1), 98–110.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*, 15 (2), 159–201.

Kamide, Y. & Mitchell, D. C. (1999). Incremental pre-head attachment in Japanese parsing. *Language and Cognitive Processes*, 14(5), 631–662.

Oishi, H. & Sakamoto, T. (2004). Tougokaiseki-ni okeru sokuji-chien syori no kensyo: P600-o shihyou to shite (Investigation on the incrementality in syntactic parsing: employing the P600 as an index). Ninchi Kagaku (*Cognitive Science*), 11, 311–318.

Osterhout, L. & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, 31, 785–804.

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.

Sturt, P. & Crocker, M. W. (1996). Monotonic syntactic processing: A cross-linguistic study of attachment and reanalysis. *Language and Cognitive Processes*, 11(5), 449–494.

Sturt, P., Scheepers, C., & Pickering, M. (2002). Syntactic ambiguity resolution after initial misanalysis: The role of recency. *Journal of Memory and Language*. 46, 371–390.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influence on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and*

Language, 33, 285–318.

Ueno, M. & Kluender, R. (2003). Event-related brain indices of Japanese scrambling. *Brain and Language*, 86(2), 243 271.