博士論文

Head Association Ambiguity in Japanese Relative Clause Processing

（日本語の関係節処理における主要部接続曖昧性）

山田　敏幸

HEAD ASSOCIATION AMBIGUITY IN JAPANESE RELATIVE CLAUSE PROCESSING

by

Toshiyuki YAMADA

B.Ed., English Education,
Gunma University (2009)

M.Ed., English Education,
Gunma University (2011)

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ABSTRACT

This dissertation examines the processing of a globally ambiguous structure in Japanese and discusses what it tells us about the nature of the human language parsing mechanism for comprehending sentences (we call this mechanism the *parser*).

The target phenomenon is the head noun ambiguity observed in certain Japanese relative clauses (RCs), as illustrated in (1).

(1) [Isi-ga syokusinsiteiru] syôzyo-no ani-ga ….
[doctor-NOM palpating] girl-GEN brother-NOM
'The brother of the girl [(that) the doctor is palpating] is ….'

The parser first receives a noun *isi-ga* ('doctor') and a verb *syokusinsiteiru* ('palpating'). At the point of the following noun *syôzyo* ('girl'), it turns out that a simple sentence analysis is impossible. The parser has to introduce a new syntactic node and *associate* this first potential head noun (N1) with the preceding material, which leads to a RC analysis, as shown by the brackets in (1). We use the term *association* for this process of forming a RC in Japanese. In ambiguous cases, as in (1), more than one RC analysis is viable. The genitive case marker *-no* attached to the N1 indicates that another noun will follow, and thus at the point of the genitive case marker or the following noun *ani* ('brother'), a second grammatically possible analysis arises because the parser can associate the second potential head noun (N2) with the RC. To achieve this new association, the parser would have to revise its initial analysis by introducing two new syntactic nodes, one for linking the N1 and N2 to form a complex noun phrase and the other for associating this complex noun phrase with the preceding RC. We call the first RC formation the *N1 association* and the second the *N2 association*. Note that revision from the N1 to the N2 association analysis is syntactically not required (i.e., if it occurs, it is *unforced*) because the ambiguity in question is global: even when the N2 association becomes available, the N1 association analysis remains grammatical and therefore could be maintained.

Previous studies on such *head association ambiguity* in Japanese RC processing have reported varying findings. The results of on-line experiments tend to support the N1 association preference at the N1 (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004; Nakano & Kahraman, 2013), while those of off-line experiments appear to support the N2 association preference at the end of the sentence (e.g., Kamide & Mitchell, 1997; Uetsuki, 2007; Nakano & Kahraman, 2013). The results from on-line self-paced reading experiments with two conditions have shown longer reading times at the N1 and N2 when the N1 was implausible as the RC head noun compared to when the N2 was implausible, providing clear evidence for the parser's consideration of the N1 association analysis upon encountering the N1. However, we still know little about the exact time course of the N2 association analysis. An interesting question is why the parser would perform such

syntactically complex processing to consider the N2 association analysis even though it does not have to revise the N1 association analysis to achieve grammaticality. This dissertation investigates the time course of the parser's construction of the N2 association analysis as well as the N1 association analysis through a series of off-line and on-line experiments and a corpus analysis.

First, we consider the results of the earlier research that showed the on-line N1 association preference and the off-line N2 association preference. These studies' results suggest that the parser considers the N1 association analysis initially, i.e., at the N1, and revises it to the N2 association analysis ultimately, i.e., at the end of the sentence. However, it is not clear when the parser performs this revision. It is possible that revision occurs at the N2, but the previous research has not provided on-line evidence regarding this possibility. It could also be the case that revision occurs after the N2. This leads to Research Question 1: Can the parser choose the N2 association interpretation based on the coherence of the whole sentence? If so, sentence-final information may affect the final choice between the two potential head nouns. A questionnaire experiment (Experiment 1) investigated comprehenders' off-line preference for RC head association. The sentence-final main clause verbs were manipulated as to whether their relationship with the RC verbs was implicitly "causal" or not (i.e., "neutral"). For example, if the sentence-final verb following the N2 in (1) above is *crying with pain*, its relationship with the RC verb is implicitly "causal" in that the RC verb *palpating* is the cause and the main verb *crying with pain* is its result. Thus, in this condition the N2 association interpretation that the person palpated by the doctor cried with pain is more plausible, compared to the N1 association interpretation that the palpated person and the crying person were different. On the other hand, if the sentence-final verb is *sitting on a chair*, its relationship with the RC verb *palpating* is not causal and both interpretations are similarly plausible, which we call the "neutral" condition. If comprehenders establish the N2 association interpretation based on the coherence of the whole sentence, they should choose it more frequently when the relationship between the two verbs is "causal" than when it is "neutral." The results of Experiment 1 indicate an overall preference for the N1 association interpretation, in contrast to the results of previous research suggesting an off-line preference for the N2 association interpretation. In addition, it is shown that the participants chose the N2 association interpretation more often when the two verbs' relationship was "causal," as we predicted. These results demonstrate that the parser establishes the N2 association interpretation by taking the meaning of the whole sentence into consideration. As for our finding of an overall preference for the N1 association interpretation, it may be due to a methodological problem, as the stimuli in the "neutral" condition may have been unintentionally biased.

The results of Experiment 1 lead to Research Question 2: Can the parser consider the N2 association analysis prior to the end of the sentence during real-time processing? To investigate this question, two on-line eye-tracking reading experiments (Experiments 2 and 3)

examined whether the parser considers the N2 association analysis at the N2 (Experiment 2) or even earlier, at the genitive case marker attached to the N1 (Experiment 3). We also investigated whether the typicality of the N1 as the RC head noun would affect the parser's willingness to revise the N1 association analysis and consider the N2 association analysis. Experiment 2 manipulated the plausibility of the N2 association analysis at the sentence-final main predicate following the N2 to examine whether comprehenders consider the N2 association analysis at the N2. The main predicates were manipulated as to whether they were compatible with the meaning conveyed by the N2 association analysis or not. If comprehenders consider the N2 association analysis at the N2 and maintain it, they should experience difficulty at the main predicate when the predicate is incompatible with the N2 association analysis. In addition, the N1s were manipulated as to whether they were "typical" for the N1 association analysis or "neutral" for both N1 and N2 association analyses. For example, in (1) above, the N1 is *the girl*. If this N1 is replaced with *a patient*, it is more likely to be modified by the RC because a patient is more typical as a person who is palpated by a doctor. The N1 *the girl* is plausible but not particularly typical as a person being palpated by a doctor, and thus is less likely to be modified by the RC. We call this "neutral" (as opposed to "typical") in that this N1 creates no bias towards either the N1 or the N2 association analysis. If the N2 association analysis occurs as a result of revision from the N1 association analysis, we can expect that the N1's typicality could affect comprehenders' willingness to consider the N2 association analysis. We predicted that when the N1 is "typical", the parser will tend to retain the initial N1 association analysis, and that when the N1 is "neutral," the parser will be more likely to perform revision, presumably because comprehenders only weakly commit to the N1 association analysis. If this is the case, greater difficulty should be observed at the main predicates that are incompatible with the N2 association analysis when the N1 is neutral as opposed to when the N1 is typical. The results of Experiment 2 confirm our first prediction: the participants showed longer reading times at the sentence-final main predicates when the predicate was incompatible with the N2 association analysis compared to when it was not, suggesting that the participants considered the N2 association analysis prior to the end of the sentence (at the latest at the N2). Furthermore, the results also indicate longer reading times at the main predicates that were incompatible with the N2 association analysis when the N1 was typical compared to when the N1 was neutral, which was not consistent with our prediction. We discuss the possibility that our manipulation of N1 typicality did not work as we intended.

Experiment 3 further examined whether comprehenders consider the N2 association analysis at the genitive case marker attached to the N1 by manipulating the plausibility of the N2 association analysis at the N2 following the marker. The parser might expect the N2 association analysis in advance upon encountering the genitive case marker, which signals that another noun will follow. The RC verbs and the N2s were newly manipulated as to whether the N2s were lexico-semantically possible as the RC head nouns in terms of animacy or not. If comprehenders expect the N2 association analysis in advance at the genitive marker,

they should experience difficulty at the N2 when the N2 is an impossible head noun for the RC. In addition, N1 typicality was manipulated as in Experiment 2. If the N2 association analysis is the result of revision from the N1 association analysis, it is conceivable that N1 typicality affects comprehenders' expectation for the N2 association analysis. We predicted that comprehenders are more likely to maintain the initial N1 association analysis when the N1 is typical as the RC head noun, and more likely to expect the N2 association analysis in advance when the N1 is neutral. If this is the case, greater processing difficulty should occur at the N2s that are impossible as the RC head nouns when the N1 is neutral compared to when the N1 is typical. The results of Experiment 3 do not indicate that the participants showed longer reading times at the N2 when it was impossible as the RC head noun compared to when it was not, contrary to our first prediction. This finding suggests that it is not always the case that the parser expects the N2 association analysis in advance at the genitive case marker attached to the N1. On the other hand, the results indicate longer reading times at the impossible N2 when the N1 was neutral compared to when it was typical, which is consistent with our second prediction. This finding, however, is suspect because our manipulation of N1 typicality did not work, as we found in Experiment 2 (the same manipulation was adopted in both experiments because they were conducted at the same time).

The results of Experiments 2 and 3 together imply that the parser considers the N2 association analysis as early as at the N2, and does not necessarily expect it at the genitive case marker attached to the N1. Our concern, however, is whether this on-line consideration of the N2 association analysis reflects revision from the N1 association analysis, which we were not able to confirm in Experiments 2 and 3 because the manipulation of N1 typicality was ineffective.

Hence, we next investigated Research Question 3: Can the parser consider the N1 association analysis at the N1 initially when both the N1 and the N2 association analyses are available at the N2? Two on-line probe recognition experiments (Experiments 4 and 5) adopted post-sentential probe recognition technique. In Experiment 4, the words in the probe recognition task were manipulated as to whether they were "related" to the N1 association interpretation established by associating the N1 with the RC or not (i.e., "non-related"). The former type of word was predicted to be primed by the N1 association interpretation while the latter was not (the words were controlled so that they were unlikely to be primed by the individual lexical items used in the sentences preceding the recognition task). Furthermore, sentence types was manipulated in the (self-paced) reading task prior to the recognition task: one sentence type contained a RC with head association ambiguity while the other type used different lexical items and did not include a RC. If the N1 association analysis is considered at the N1 during on-line processing, faster response times should be found for the probe words "related" to the N1 association interpretation, which is based on that analysis, compared to the "non-related" words, when the sentence in the reading task contains a RC. The results of Experiment 4 show such a priming effect, suggesting that the participants established the N1

association interpretation before the end of the sentence. Furthermore, the results indicate a bias towards the N2 association interpretation in the comprehension check task that followed the recognition task. These results imply that the parser first established the N1 association interpretation prior to the recognition task, and then later reinterpreted the RC head noun from the N1 to the N2.

In Experiment 5, the words in the probe recognition task were manipulated as to whether they were "related" to the N2 association interpretation constructed by associating the N2 with the RC or "non-related" (the words were controlled as in Experiment 4). Sentence type was also manipulated as in Experiment 4. If the parser considers the N2 association analysis at the N2 as shown in Experiment 2, faster response times should be found for the probe words "related" to the N2 association interpretation, compared to the "non-related" words, when the sentence contains a RC. The results of Experiment 5 show no significant difference in response times between the "related" and "non-related" words when the sentences contained RCs. However, the results indicate that the participants showed a preference for the N2 association interpretation in the comprehension task, and further, that they chose the N2 association interpretation more often when the "related" words appeared in the recognition task prior to the comprehension task. A question remains as to why we did not observe a significant interaction of the two manipulations as a result of the priming effect. We argue that, if, as suggested in Experiment 1, the parser considers the coherence of the whole sentence to arrive at the N2 association interpretation, this interpretation may take longer to establish than the N1 association interpretation. Hence, the N2 association interpretation may not have been sufficiently established at the time of the probe recognition task to produce an effect as robust as the effect observed for the N1 association interpretation in Experiment 4.

The results of Experiments 4 and 5 together suggest that the N1 association interpretation is established by the end of the sentence. Based on these experiments' results and the earlier studies' findings of an on-line preference for the N1 association analysis, it follows that the parser considers the N1 association analysis at the N1 even when the N2 association analysis is viable at the N2. Furthermore, the results of Experiments 4 and 5 imply that even after the N1 association interpretation is established, comprehenders may change their ultimate interpretation from the N1 to the N2 association (although they do not have to do so).

Finally, the dissertation tackled the remaining issue of why the parser considers the N2 association analysis at all, when the N1 association analysis can be retained at the N2. To address this question, a corpus analysis examined Research Question 4: Do RC production data show a structural frequency bias towards the N2 association? The assumption is that if the N2 association interpretation is more frequently intended in production, comprehenders should experience the N2 association more often, compared to the N1 association, and thus be more likely to consider the N2 association analysis in their processing. We examined structural frequency as a possible factor triggering unforced revision. The results of the corpus analysis show no advantage for the N2 association, suggesting that a structural frequency bias

cannot account for why comprehenders attempt the N2 association analysis by revising the initial grammatical N1 association analysis.

In sum, this dissertation asks why comprehenders can consider the N2 association analysis in their processing of head association ambiguity in Japanese RCs even though they do not have to revise their initial grammatical N1 association analysis. We specifically examine the time course of the N2 association analysis as well as the N1 association analysis. The results of Experiment 1 suggest that the parser establishes the N2 association interpretation based on the coherence of the whole sentence. The results of Experiments 2 and 3 imply that the parser considers the N2 association analysis at the N2 and does not necessarily expect it at the genitive case marker attached to the N1. The results of Experiments 4 and 5 imply that the N1 association interpretation is established by the end of the sentence, while the N2 association interpretation appears to take a longer time to establish compared to the N1 association interpretation. Finally, the results of the corpus analysis suggest that structural frequency cannot explain the parser's consideration of the N2 association analysis as a result of unforced revision from the N1 association analysis, and thus that other factors must be involved.

Based on these results together, this dissertation argues that the parser first considers the N1 association analysis immediately upon encountering the N1 and then revises it to consider the alternative N2 association analysis at the N2 when the N2 is possible as the RC head noun. After that, if the parser establishes the N2 association interpretation at the end of the sentence, it does so based on the coherence of the whole sentence, which leaves open the possibility of a final N1 association interpretation instead. The results of the parser's consideration of the N2 association analysis at the N2 during on-line processing are of theoretical importance because they support the claim that unforced (i.e., syntactically not required) revision exists in human language parsing, contrary to the Revision as Last Resort hypothesis, which assumes that revision is applied only when the current analysis turns out to be syntactically ill-formed or ungrammatical (Fodor & Frazier, 1980). As for the remaining question of why the parser considers the N2 association analysis at the N2, we discuss the possibility that general mechanisms of processing RCs in Japanese may be involved. According to the tree-lowering operation (Sturt & Crocker, 1996), the parser first associates the N1 with the preceding RC (the N1 association analysis), then lowers the N1 to the adjunct position for the complex noun phrase headed by the N2, and finally associates the N2 (i.e., the complex noun phrase) with the RC (the N2 association analysis). It would then follow that revision from the N1 to the N2 association analysis is a natural transition in the processing of Japanese RCs with head association ambiguity. Furthermore, we note that unforced revision occurs in rather limited environments cross-linguistically such as head-final constructions in English (e.g., *the recently divorced bishop's daughter*; Fodor & Inoue, 2000), and the corresponding ambiguous adjectival phrases in Japanese (e.g., Inoue & Fodor, 1995)), and propose that head-finality may be a key factor in the availability of unforced revision, as discussed in some earlier studies (e.g., Aoshima, Phillips, & Weinberg, 2004). This proposal is in line with the

"tentative attachment strategy" (Mazuka & Itoh, 1995) by which the parser actively attaches incoming information to preceding material and evaluates its "tentative" analyses in light of further incoming disambiguating information. Thus, revision from the N1 to the N2 association analysis follows a natural course of processing head-final structures.

Given the existence of unforced revision in language, we discuss what it tells us about parsing models, in particular the serial modular and ranked-parallel interactive models. Serial models assume that only one analysis is entertained at a time, and modular models assume that different kinds of information are used at different times during the construction of a syntactic analysis, with syntactic information being used first. For serial parsing, our results suggest that the parser considers the N1 association analysis initially at the N1 and then revises it to the N2 association analysis at the N2. Furthermore, our results imply that depending on the animacy information of the N2, the parser maintains the initial N1 analysis at the N2 when the N2 is an impossible head noun for the RC, and considers the alternative N2 analysis at the N2 when the N2 is possible as the RC head noun. This is consistent with the notion of "probabilistic" serial parsing, which assumes that, at an ambiguous point, the parser can consider one analysis at some times and another at other times according to the probability of each possible analysis (Lewis, 2000). On the other hand, our findings are not consistent with a "deterministic" serial model, which would assume that, at an ambiguous point, only one analysis is ever considered due to parsing principles that are insensitive to lexico-semantic information such as animacy. As for modular parsing, our results suggest that kinds of information other than syntactic are involved in the parser's consideration of the N2 association analysis at the N2 because revision from the N1 association analysis to the N2 association analysis is syntactically not required. A strictly staged parser like the *Garden-path Model* cannot account for our observations, which imply that the parser does or does not consider the N2 association analysis depending on the animacy of the N2. Our results suggest that the on-line construction of the N2 association analysis at the initial stage is dependent on lexico-semantic information, which is a different level of information from syntactic information, and thus would be assumed by modular models to have no immediate impact on on-line parsing.

Ranked-parallel models assume that more than one analysis are considered simultaneously at a time, and the most motivated analysis is ranked the highest in terms of our awareness. Interactive models assume that multiple sources of information are used during the on-line consideration of these multiple analyses. For ranked-parallel parsing, our results imply that after the N1 association analysis is considered at the N1, the N2 association analysis is ranked higher at the N2 compared to the N1 association analysis. Thus, the parser's consideration of the N2 association analysis at the N2 reflects such re-ranking. As for interactive parsing, our results suggest that the N2 association analysis at the N2 is motivated by sources of information other than grammaticality. For example, we consider parsing principles such as Predicate Proximity (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) and Main

Assertion Principle (Traxler & Frazier, 2008). This interactive account is in line with our results that the parser uses the lexico-semantic information of the N2 during the on-line construction of the N2 association analysis.

In conclusion, our findings regarding unforced revision from the N1 to the N2 association analysis in the processing of Japanese RCs tell us that the parser must possess three characteristics: it permits unforced revision (syntactically not required consideration of an alternative analysis); it is driven by probabilistic processing (evaluation at each point of each possible parse according to its probability); and it is driven by interactive processing (evaluation of each possible parse based on multiple sources of information available at the point in question). Although our results were not able to tease apart serial and (ranked-)parallel parsers, these characteristics are all captured better by the latter model of parsing, which is consistent with a number of recent psycholinguistic studies on sentence processing.

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LIST OF ABBREVIATIONS

ACC	ACCusative case marker
β	estimated coefficient (statistical terminology)
DAT	DATive case marker
DECL	DECLarative complementizer
GEN	GENitive case marker
LME	Linear Mixed-Effects
LOC	LOCative case marker
ms	millisecond(s)
N	Noun
N1	The first potential head noun for a relative clause
N2	The second potential head noun for a relative clause
NOM	NOMinative case marker
NP	Noun Phrase
p	*p* value (statistical terminology)
P	Preposition
PP	Preposition Phrase
RaLR	Revision as Last Resort (hypothesis)
RC	Relative Clause
Q	Question particle
S	Sentence
SD	Standard Deviation (statistical terminology)
SE	Standard Error (statistical terminology)
t	*t* value (statistical terminology)
TOP	TOPic marker
V	Verb
VP	Verb Phrase
z	*z* value (statistical terminology)

To my precious memories of
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my grandfather, Hiroshi YAMADA (1926-2016),
our friendly dog, Luke (2006-2016),
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This dissertation is dedicated to
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CHAPTER 1

INTRODUCTION

1.1. Problems to Be Tackled

How do we process structural ambiguity when more than one sentence structure is possible with a single string of words? The goal of the present dissertation is to examine certain aspects of a structural ambiguity phenomenon in Japanese and discuss what this phenomenon tells us about the nature of the human language processing mechanism for comprehending sentences (we call this mechanism the *parser*). Specifically, the dissertation questions whether the parser can change its initial analysis, choosing an alternative, even when the initial analysis can be retained.

The target phenomenon is an ambiguous structure with relative clause (RC) modifiers as illustrated in (1.1) (GEN stands for GENitive case marker and NOM for NOMinative case marker).[1]

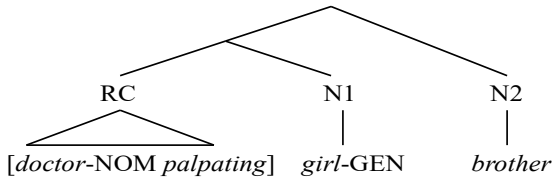
(1.1) [isi-ga syokusinsiteiru] syôzyo-no ani
[$_{RC}$ doctor-NOM palpating] girl-GEN brother
'the brother of the girl that the doctor is palpating'

In Japanese, a RC precedes its head noun; it is not marked by a relativizer or a special ending on the RC verb. The prenominal RC in brackets in (1.1) can modify either the first potential head noun (hereafter N1) *syôzyo* ('girl') as in (1.2a) or the second potential head noun (hereafter N2) (*syôzyo-no*) *ani* ('(girl's) brother') as in (1.2b) (English glosses are shown in

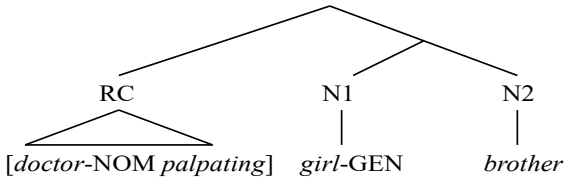
[1] This phenomenon has been called *RC attachment ambiguity* and examined cross-linguistically since a study by Cuetos and Mitchell (1988). Chapter 2 provides a detailed review of previous studies on this kind of ambiguity.

italics).

(1.2) a.

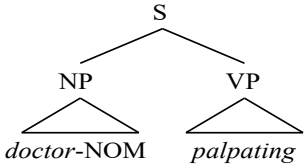


b.



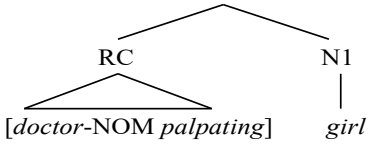
The analysis in (1.2a) means that it is the girl whom the doctor is palpating, whereas the one in (1.2b) means that it is the girl's brother whom the doctor is palpating. It is important to note that both analyses are grammatical (i.e., syntactically well-formed) in Japanese (1.1), and thus that the structural ambiguity in question is global, not temporary. Let us observe the word-by-word parsing of (1.1). First, the parser is expected to build a simple sentence structure as in (1.3) (S indicates a Sentence, NP a Noun Phrase, and VP a Verb Phrase) because a sequence of *isi-ga syokusinsiteiru* ('doctor-NOM palpating') is a grammatical sentence in Japanese with an unpronounced direct object, meaning that the doctor is palpating someone.

(1.3) Simple sentence analysis



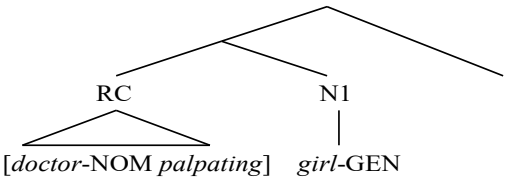
Upon encountering the following noun, however, it turns out that the parser cannot construct a simple sentence analysis and thus has to introduce a new syntactic node to *associate* this first potential head noun (N1) with the preceding material, leading to the RC analysis as in (1.4).

(1.4) RC analysis



We use the term *association* to describe this type of operation for forming a RC in Japanese (for the term, see Hirose, Inoue, Fodor, & Bradley, 1998; Hirose, 1999). After that, the parser encounters a genitive case marker *-no* attached to the N1 and may introduce a higher syntactic node to form a complex NP, as shown in (1.5), because the marker implies that another noun will follow.[2]

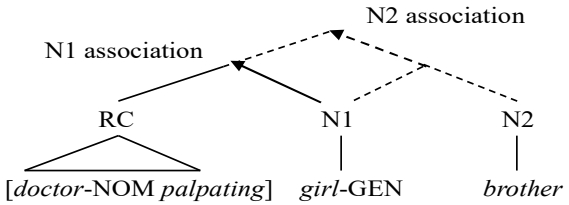
(1.5) The existence of the N2 expected



Thus, either at the genitive case marker attached to the N1 or at the second potential head noun (N2), a second possibility arises, which is that the parser can associate the N2 with the preceding RC. To achieve this, the parser has to introduce a new syntactic node to form a complex NP by combining the N1 and the N2 and associate this complex NP with the RC. In this way, ambiguity occurs as in (1.6).

[2] See Miyamoto (2002) for a discussion of how case-marker information is used in Japanese sentence processing.

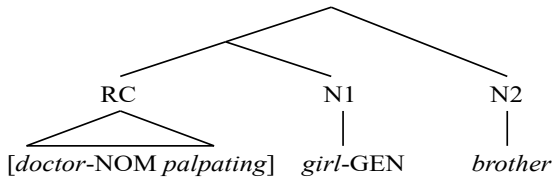
(1.6) *Head association ambiguity*



We call the first RC formation the *N1 association* and the second the *N2 association* (in fact, the whole complex NP *syôzyo-no ani* ('girl's brother') associates with the RC, but we will call it the N2 association for expository purposes). We term this phenomenon *head association ambiguity* or *RC head association ambiguity*.

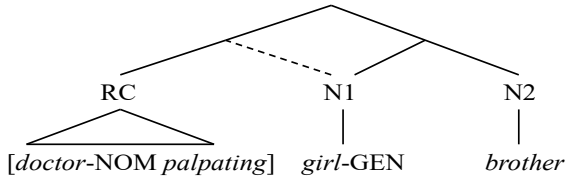
The question tackled in the present dissertation is whether the parser can change the initial N1 association analysis for the alternative N2 association analysis even when it does not have to do so for grammaticality; and if so, at which point it would consider the N2 association analysis. One possibility is that the initial N1 association analysis remains unchanged as in (1.7).

(1.7) N1 association analysis unchanged



Because both N1 and N2 association analyses are grammatical, the parser is not required by syntax to change the initial N1 association analysis for the N2 association analysis. Nonetheless, another possibility is that the parser considers changing the N1 association analysis to the alternative N2 association analysis as in (1.8).

(1.8) Change from the N1 association analysis to the N2 association analysis



This possibility arises when the parser encounters the genitive case marker or the N2, which triggers the change from the N1 association analysis to the N2 association analysis, as indicated by the broken line in (1.8), even though such a change is by no means motivated by syntax. We call this process *unforced revision*.

There is a puzzling fact about this RC head association ambiguity phenomenon. The results of earlier studies have been mixed; some studies (e.g., Kamide & Mitchell, 1997; Kamide, Mitchell, Fodor, & Inoue, 1998; Miyamoto, Gibson, Pearlmutter, Aikawa, & Miyagawa, 1999; Miyamoto, Nakamura, & Takahashi, 2004; Nakano & Kahraman, 2013) show a preference for the N1 association analysis, which is consistent with the first possibility (1.7), and others (e.g., Kamide & Mitchell, 1997; Uetsuki, 2007; Nakano & Kahraman, 2013) show a preference for the N2 association analysis, which is consistent with the second possibility (1.8). One possible reason for these studies' differing results is the difference in their experimental methods, either on-line or off-line. The results from on-line self-paced reading experiments tend to support the N1 association preference while the results from off-line questionnaire experiments tend to support the N2 association preference. The mixed results of previous research led Kamide and Mitchell (1997) to suggest the possibility, which remains unconfirmed, of *unforced* (i.e., syntactically not required) revision in resolving the head association ambiguity in Japanese RC processing. They proposed that Japanese comprehenders consider the N1 association analysis initially, and then revise it to the N2 association analysis even when the initial analysis remains grammatical. To verify whether

unforced revision actually does take place, we would need evidence both for the initial commitment to the N1 association analysis and for the time course of the change from the N1 to the N2 association analysis. The previous on-line studies (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004) tested only two conditions, in which readers are forced to adopt either the N1 or N2 association analysis at the point of encountering the N2. These studies showed that the participants experienced greater processing difficulty at the N1 when the N1 was implausible as the RC head noun, compared to when the N2 was the implausible RC head noun. This is clear evidence for the parser's consideration of the N1 association analysis upon encountering the N1. Although earlier studies (e.g., Kamide & Mitchell, 1997) provided off-line evidence for the N2 association analysis preference, we still know little about the exact time course of unforced revision from the initial N1 association analysis to the alternative N2 association analysis.

The phenomenon of RC head association ambiguity in Japanese is highly relevant to test a hypothesis known as *Revision as Last Resort* (1.9).

(1.9) Revision as Last Resort (hereafter RaLR)
[T]he partial phrase marker that has been constructed on the basis of previous words in the sentence is not to be *changed* in response to subsequent words unless there is no other way of proceeding.
(Fodor & Frazier, 1980: 427, emphasis original)

"The partial phrase marker" in (1.9) means the sentence structure under construction. The reason revision is considered to be a *last resort* is that revision apparently is not applied unless the unrevised analysis is ungrammatical or syntactically ill-formed (see Fodor & Frazier, 1980: 427, footnote 6). The idea of last resort has received both theoretical and empirical support. Theoretically, it is consistent with the assumption that it is computationally efficient not to apply revision unless it is forced by syntax (e.g., the Minimal Revisions Principle of

Frazier, 1990a, and the Minimal Revision Principle of Inoue, 1991).[3] Fodor and Frazier (1980) argued that the parser abides by RaLR; otherwise, it would be very inefficient "for the parser to switch from one analysis to another in the absence of any good reason to do so" (p. 427). Empirically, the RaLR hypothesis is supported by some earlier studies, which showed that revision is indeed applied as a last resort (e.g., Kamide & Mitchell, 1999, in Japanese; Schneider & Phillips, 2001; Sturt, Pickering, Scheepers, & Crocker, 2001, in English). We will review these studies in detail in Chapter 2.

To verify the existence of unforced revision, which would counter the RaLR hypothesis, is of theoretical importance because it tells us about the nature of the human language processing mechanism if it can incorporate syntactically unmotivated processes. Testing unforced revision in *head-final* languages such as Japanese is helpful because disambiguating information often appears at the clausal end in these languages. Although the RaLR hypothesis does not permit unforced revision of any sort in the processing of structural ambiguity, several studies in Japanese sentence processing have reported results that provide support for revision that is not forced by syntax. Studies have demonstrated unforced revision in the processing of left/right-branching modifier ambiguity in Japanese (Inoue & Fodor, 1995; Hirose, Inoue, Fodor, & Bradley, 1998; Hirose, 1999; Fodor & Inoue, 2000) and main/embedded clause ambiguity in Japanese (Aoshima, Phillips, & Weinberg, 2004; Kanamaru, Ito, & Hirose, 2009). This research will be reviewed in detail in Chapter 2. The present dissertation tests the RaLR hypothesis by examining RC head association ambiguity as another type of structural ambiguity in Japanese. In fact, the head association ambiguity in Japanese provides an excellent testing ground for unforced revision because the two potential head nouns, N1 and N2, both occur after the RC, and, more crucially, the N1 association analysis can be considered before the N2 association analysis becomes available.

[3] These principles as well as RaLR are sub-principles of *Minimal Everything*, "a general least effort principle" (Inoue & Fodor, 1995: 35).

1.2. Theoretical Framework and Assumptions

This section outlines the theoretical framework and assumptions regarding the parser on which this dissertation research is based.

Serial and ranked-parallel models of parsing

We first consider two contrasting types of processing account (e.g., Gorrell, 1987, 1989; Gibson & Pearlmutter, 2000; Lewis, 2000, among many others). Broadly speaking, the parser has been modeled as either *serial modular* or *ranked-parallel interactive* in terms of the kinds of information it uses for an initial analysis in the processing of temporarily ambiguous structures (e.g., Crocker, 1999; Clifton, 2000; Pickering, Clifton, & Crocker, 2000; Traxler, Pickering, Clifton, & van Gompel, 2000; Pickering & van Gompel, 2006; van Gompel & Pickering, 2007). The *Garden-path Model* is one of the serial modular approaches (e.g., Frazier, 1979). The basic assumption of this model is that a single analysis of sentence structure is constructed at a time in consideration of parsing principles or strategies that are exclusively based on syntactic information, and that other kinds of information are made available for use in examining and revising (when necessary) the currently constructed structure. Furthermore, in this 'syntax-first' model, comprehenders commit to a single analysis based on parsing principles in the initial stage. Consider the left-to-right processing of the familiar garden-path sentence in (1.10).

(1.10) The horse raced past the barn fell.

(Bever, 1970)[4]

The verb *raced* is temporarily ambiguous in that it can belong to the main clause or to the (reduced) relative clause. Following a parsing principle called *Minimal Attachment* that

[4] Some recent studies suggest that the apparent garden-path effect in the sentence in (1.10) is attributable not to processing difficulty but simply to grammatical unacceptability (e.g., McKoon & Ratcliff, 2003; cf. Hare, Tanenhaus, & McRae, 2007). The sentence is used here, however, only to provide a schematic illustration of the effect.

requires the parser to construct the simplest syntactic structure whenever possible (Frazier, 1979), English speakers prefer to adopt the main-clause analysis at first. Notice that this analysis is correct until the sentence-final verb *fell* occurs. In other words, there is no grammatical reason to revise the initial analysis up to the point of *fell*. The analysis, however, turns out to be incorrect at *fell*, resulting in a garden-path effect. This effect suggests that kinds of information other than syntactic are not used in the initial analysis. Moreover, it is also consistent with Revision as Last Resort because revision from the incorrect main-clause analysis to the correct relative-clause analysis is not applied until the sentence-final disambiguating verb *fell* signals that the initially adopted main-clause analysis cannot be maintained for grammaticality. In other words, the parser appears not to commit to the alternative correct relative-clause analysis at *raced*, which causes the temporary ambiguity. The serial models have been supported empirically (e.g., Frazier & Rayner, 1982; Rayner, Carlson, & Frazier, 1983; Ferreira & Clifton, 1986; Frazier, 1987; Rayner, Garrod, & Perfetti, 1992; Frazier, 1995; Frazier & Clifton, 1996; Clifton, Traxler, Mohamed, Williams, Morris, & Rayner, 2003, among many others).

As a ranked-parallel interactive model, the *Lexicalist Constraint-based Model* takes a different approach to the processing of temporary ambiguity (e.g., MacDonald, Pearlmutter, & Seindenberg, 1994). This model assumes that multiple analyses are considered simultaneously, and that these analyses are ranked according to how likely each analysis is with reference to multiple sources of information (called *constraints*) such as phonological, morphological, lexical, syntactic, semantic, and pragmatic information, lexical/structural frequency, plausibility, and so on. In other words, comprehenders evaluate more than one structural analysis in terms of constraint satisfaction. Consider the sentences in (1.11a-b).

(1.11) a. The defendant examined by the lawyer turned out to be unreliable.
b. The evidence examined by the lawyer turned out to be unreliable.
(Trueswell, Tanenhaus, & Garnsey, 1994: 286)

Trueswell, Tanenhaus, and Garnsey (1994) examined the on-line sentence comprehension of (1.11a-b) and found processing difficulty with (1.11a) only (cf. Ferreira & Clifton, 1986: Experiment 1). In (1.11b), the animacy information of *evidence* is used to resolve ambiguity, leading to the correct relative-clause analysis prior to the disambiguating main verb *turned*. In (1.11a-b), at *examined*, the main-clause and relative-clause analyses are both *activated* (i.e., taken into consideration), but the degree of their activation is different between (1.11a) and (1.11b). In (1.11a), the main-clause analysis is *ranked higher* for activation (i.e., closer to the threshold of adoption), compared to the relative-clause analysis, because the verb *examined* requires its subject to be animate and the subject *defendant* is animate. In (1.11b), on the other hand, the relative-clause analysis is ranked higher because *evidence* is inanimate and thus not a good candidate for the subject of *examined*. Hence, in (1.11a) the initial (incorrect) main-clause analysis has to be re-ranked at *turned*, resulting in processing difficulty, whereas the initial (correct) relative-clause analysis can be maintained at *turned* in (1.11b). The ranked-parallel models have also been supported empirically (e.g., Tyler & Marslen-Wilson, 1977; Waltz & Pollack, 1985; Altmann & Steedman, 1988; Taraban & McClelland, 1988; Bates & MacWhinney, 1989; Trueswell & Tanenhaus, 1991; MacDonald, 1993; Trueswell, Tanenhaus, & Kello, 1993; Pearlmutter & MacDonald, 1995; Spivey-Knowlton & Sedivy, 1995; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Trueswell, 1996; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Tabor, Juliano, & Tanenhaus, 1997; Boland & Boem-Jernigan, 1998; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Spivey & Tanenhaus, 1998; Tabor & Tanenhaus, 1999; Vosse & Kempen, 2000; Boland & Blodgett, 2001; Tabor & Hutchins, 2004, among many others).

In the present dissertation, we temporarily follow both serial modular and ranked-parallel interactive models of parsing and discuss theoretical implications of our experimental results for both models.

Incremental parsing

Second, we assume that sentence parsing is *incremental* in that the parser constructs syntactic structures roughly in a word-by-word fashion without delaying until more information becomes available. For example, consider the sentence in (1.11a) again, repeated as (1.12) here.

(1.12) The defendant examined by the lawyer turned out to be unreliable.

If the parser could delay its syntactic analysis, waiting for the disambiguating main verb, and construct the correct relative-clause analysis at *turned*, no processing difficulty would occur, contrary to the experimental results. There is a great deal of cross-linguistic literature that is consistent with the incremental nature of parsing (e.g., Frazier, 1987; Altmann & Steedman, 1988; MacDonald, Pearlmutter, & Seidenberg, 1994; Inoue & Fodor, 1995; Mazuka & Itoh, 1995; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Kamide & Mitchell, 1999; Schneider, 1999; Miyamoto, 2002; Aoshima, 2003; Aoshima, Phillips, & Weinberg, 2004; Kamide, 2006, among many others).[5] In this dissertation, we explicate the time course of unforced revision from the initial analysis to the alternative analysis in incremental terms.

Anticipatory parsing

Finally, we assume that sentence parsing is *anticipatory* in that it is possible for the parser to construct the upcoming syntactic structures in advance on the basis of the previously received information (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Altmann & Kamide, 1999; Kamide, Altmann, & Haywood, 2003; Knoeferle, Crocker, Scheepers, & Pickering, 2005; Kamide, 2008, among many others). The so-called *Surprisal* or *Expectation-based Model* considers the role of probabilities in the real-time processes of

[5] Some previous studies, however, suggest that the use of certain types of information to construct syntactic structures is delayed (e.g., Mitchell, 1987; Pritchett, 1991).

parsing (e.g., Hale, 2001; Levy, 2008). In parsing, we continuously generate expectations, based on the previously received words, for the upcoming words or structures (Marslen-Wilson, 1975). Compare the continuums in (1.13a-b), for example.

(1.13) a. At the hamburger shop, the man ate the …
b. At the hamburger shop, the man saw the …

In (1.13a), we strongly expect something edible to come (in fact, the incoming material is biased towards foods provided in a hamburger shop, for example, a cheeseburger). In (1.13b), however, we are open to many possibilities of what is to come (e.g., a girl, a car, a shop manager, and so forth). The continuum in (1.13a) is proven to be easier to process than that in (1.13b) (e.g., Ehrlich & Rayner, 1981). The degree to which a single word contributes to the information for expectation differs from word to word; therefore, the cognitive load imposed by the processing of a word is termed the *surprisal* of the word in the context in which it shows up (Hale, 2001). This word-by-word expectation has been demonstrated to influence sentence parsing, and lexically specific and independent (i.e., structural) probabilities have been discussed as playing a role in processing (e.g., Jurafsky, 1996, 2003; Narayanan & Jurafsky, 1998, 2002; Hale, 2001; Levy, 2008). In the target RC structure that we examine in this dissertation, the genitive case marker attached to the N1 makes the parser expect that another noun (i.e., the N2) will follow the marker. We will discuss how this expectation could influence comprehenders' processing of RC head association ambiguity.

1.3. Organization

In this introductory chapter, we have looked at the primary goal of this dissertation and the theoretical framework and assumptions about the parser on which the dissertation study is based. The goal is to examine the phenomenon of head association ambiguity in Japanese RC processing, which will help us further explicate the nature of the human sentence parsing

mechanism.

The subsequent chapters are organized as follows. Chapter 2 reviews earlier studies on three relevant topics for this dissertation: revision in sentence parsing, RC attachment ambiguity mainly in English, and head association ambiguity in Japanese RCs. Chapter 3 presents the four research questions that guide this study's investigation of (i) whether the parser can choose the N2 association interpretation based on the coherence of the whole sentence, (ii) whether the parser can consider the N2 association analysis prior to the end of the sentence during real-time processing, (iii) whether the parser can consider the N1 association analysis at the N1 initially when both the N1 and the N2 association analyses are available at the N2, and (iv) whether RC production data show a structural frequency bias towards the N2 association. Chapter 4 reports the results of an off-line questionnaire experiment and provides a positive answer to Question (i), suggesting that the information of the main and relative clauses influences comprehenders' choice of the N2 association interpretation. Chapter 5 reports the results of two on-line eye-tracking reading experiments and provides a positive answer to Question (ii), implying that the parser considers the N2 association analysis at the N2. Furthermore, it is suggested that the parser does not necessarily expect the N2 association analysis in advance at the genitive case marker attached to the N1. Chapter 6 reports the results of two on-line probe recognition experiments and provides a positive answer to Question (iii), implying that the parser initially considers the N1 association analysis at the N1 even when the N2 association analysis is available as well. Chapter 7 presents the results of a corpus analysis, providing a negative answer to Question (iv). In Chapter 8, we discuss the results from these chapters together and their theoretical implications for human language parsing. Finally, Chapter 9 concludes this dissertation and suggests issues for future research.

CHAPTER 2

EARLIER STUDIES

2.1. Introduction

In this chapter, we review previous studies on three topics that are relevant for this dissertation: (i) revision in sentence parsing, (ii) relative clause (RC) attachment ambiguity, and (iii) head association ambiguity in Japanese RC processing. For (i), a variety of accounts have been proposed in answer to the question of how we consider a second potential parse after the initial one, but we will focus on the Revision as Last Resort hypothesis and review both supporting and counter evidence for it. As for (ii), a great deal of research has been conducted on the cross-linguistic variation in parsing preferences for resolving RC attachment ambiguity. We will focus on previous findings on RC attachment in English. Finally, regarding (iii), which is particularly important for the present dissertation, previous investigations of head association ambiguity in Japanese RCs have reported mixed results for the N1 and the N2 association preferences. Moreover, we still know little about the time course of the process in which the parser arrives at the N2 association analysis after an initial N1 association analysis.

2.2. Revision in Sentence Parsing

Initial analysis

Comprehenders process words incrementally and adopt one possible structural analysis without delaying (i.e., without waiting for disambiguating information) when they are faced with temporarily ambiguous sentences. The two approaches to parsing define the *initial analysis* differently. In the serial modular models, the initial analysis is the one that is

computed minimally in terms of syntactic information only (see, e.g., Frazier, 1979, 1987; Frazier & Rayner, 1982; Ferreira & Clifton, 1986; Frazier & Clifton, 1996; Clifton, Traxler, Mohamed, Williams, Morris, & Rayner, 2003). In the ranked-parallel models, on the other hand, the initial analysis is defined as the one that is most supported by both syntactic and extra-syntactic (e.g., pragmatic, visual, and so on) information (see, e.g., Waltz & Pollack, 1985; Altmann & Steedman, 1988; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Garnsey, 1994; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Vosse & Kempen, 2000; Tabor & Hutchins, 2004). Consider the following example:

(2.1) The evidence examined by the lawyer turned out to be unreliable.

For the serial modular models, the initial analysis at *examined* is the main-clause analysis because it is syntactically the simplest. As for the ranked-parallel interactive models, on the other hand, the initial analysis at *examined* is the relative-clause analysis. This is because at *examined* both the main-clause and relative-clause analyses are activated and the relative-clause analysis is ranked higher due to the animacy information of *evidence* (i.e., inanimate *evidence* is not a good candidate for the subject of *examined*, and thus provides less support for the main-clause analysis).

Revision

If the initial analysis turns out to be right in the processing of a temporarily ambiguous sentence such as (2.1) above, there is no problem. Otherwise, however, comprehenders have to revise the initial analysis and consider the alternative correct one. In this dissertation, we define the term *revision* as the operation in which a second possible analysis is considered instead of the initial analysis (see Fodor & Ferreira, 1998, and references therein). For this operation too, the two models of parsing have different assumptions. In the literature on serial

modular parsing, the term *reanalysis* is often used to refer to this operation and defined thus: the alternative analysis is adopted when the initial one becomes syntactically incompatible with incoming material. In the literature on ranked-parallel interactive parsing, on the other hand, the term *re-ranking* is used, and defined as follows: the alternative analysis is adopted when the initial one becomes ranked lower according to the information available. For example, consider the following sentence:

(2.2) The defendant examined by the lawyer turned out to be unreliable.

The serial modular parser adopts the main-clause analysis at *examined*, but that initial analysis becomes syntactically incompatible at *turned* and is reanalyzed to the correct relative-clause analysis. The ranked-parallel interactive parser activates both main-clause and relative-clause analyses at *examined*, but at this point the main-clause analysis is ranked higher because the *defendant* is a good candidate for the subject of *examined*. At *turned*, however, this initial analysis turns out to be difficult to maintain for grammaticality; re-ranking has to occur, and the initial analysis now ranked lower. In this dissertation, we temporarily use *revision* as it can cover the concepts of both *reanalysis* and *re-ranking*, and we define the term as the process in which a second analysis is considered instead of the initial one.

The Revision as Last Resort hypothesis

Revision as Last Resort, repeated here in (2.3), is a long-standing hypothesis about revision processes in human language parsing.

(2.3) Revision as Last Resort (hereafter RaLR)
> [T]he partial phrase marker that has been constructed on the basis of previous words in the sentence is not to be *changed* in response to subsequent words unless there is no other way of proceeding.
>
> (Fodor & Frazier, 1980: 427)

Revision is assumed to be the *last resort* in that the human language parser should not change or revise a currently constructed syntactic structure unless it turns out to be ungrammatical or syntactically ill-formed (Fodor & Frazier, 1980: 427, footnote 6). RaLR has been empirically tested (e.g., Frazier, 1990a; Sturt & Crocker, 1996; papers in Fodor & Ferreira, 1998)[6], but Fodor and Inoue (2000) argued that it is too strong to explain all the available data. In what follows, we first review supporting evidence for RaLR, and we then look at the counter evidence, which motivates our research in this dissertation.

Supporting evidence for RaLR

Against Fodor and Inoue's (2000) criticism, some empirical evidence appears to support RaLR. For instance, Schneider and Phillips's (2001) results from two self-paced reading experiments support RaLR. The target items from the first experiment appear in (2.4a, c), with their respective unambiguous counterparts in (2.4b, d).

(2.4) a. The creative woman [who knows *the funny man* wrote some comedy sketches *himself* about the amusing escapades] thinks he should publish them.
b. The creative woman [who knows *that the funny man* wrote some comedy sketches *himself* about the amusing escapades] thinks he should publish them.
c. The creative woman [who knows *the funny man*] wrote some comedy sketches *herself* about the amusing escapades she had seen.
d. The creative woman [who knows *him*] wrote some comedy sketches *herself* about the amusing escapades she had seen.

(Schneider & Phillips, 2001: 312, (7a-d), emphasis original, brackets added)

In (2.4a), *the funny man* is favored as the object of *know* in terms of *locality*, which captures the fact that it is easier for the parser to process two elements that are close to each other (Kimball, 1973; Frazier, 1987; Gibson, Pearlmutter, Canseco-González, & Hickok, 1996;

[6] The empirical research on RaLR has been conducted mainly in the context of serial modular parsing. The hypothesis is, however, worth investigating in the framework of ranked-parallel interactive parsing as well (see Vosse & Kempen, 2000, for inclusion of RaLR in this model).

Phillips & Gibson, 1997). However, this analysis has to be revised at the reflexive pronoun *himself* in order for *the funny man* to be the subject of *wrote* and agree with *himself*. In (2.4c) too, *the funny man* is favored as the object of *know*, but this analysis can be maintained because the main-clause subject *the creative woman* agrees with *herself*. In sum, (2.4a) requires revision, although *man* and *wrote* are linearly local and thus revision is relatively easy to apply (Sturt, Pickering, & Crocker, 1999). On the other hand, (2.4c) needs no revision, although the linear distance between the reflexive pronoun (*herself*) and its antecedent (*woman*) becomes longer compared to (2.4a). As for the baseline conditions, *the funny man* is interpreted unambiguously as the subject of *wrote* in (2.4b) thanks to the complementizer *that*, whereas *him* is analyzed unambiguously as the object of *know* in (2.4d) due to its accusative form. Schneider and Phillips (2001) observed a significant difference in reading times at *about*, the word immediately following the disambiguating reflexive pronoun, between (2.4a) and (2.4b), but not between (2.4c) and (2.4d). The participants took longer to read *about* in (2.4a), compared to (2.4b). These results suggest that revision of *the funny man* from the object of *know* to the subject of *wrote* was not attempted prior to the reflexive pronoun in (2.4a). This is consistent with RaLR because, in (2.4a), the continuation *knows the funny man wrote* with the *funny man* as the object is grammatical up to the reflexive pronoun. The finding of the preference for high attachment of *wrote* to the main clause was replicated in the second experiment of Schneider and Phillips (2001).

Sturt, Pickering, Scheepers, and Crocker (2001) provided another piece of self-paced reading evidence that supports RaLR. Three self-paced reading experiments were carried out to distinguish three hypotheses about revision processes in parsing: (i) the *Revision-as-Last-Resort Hypothesis*, as one extreme, that the parser should not make revision unless forced to do so for syntactic reasons (in the sense of Fodor & Frazier, 1980), (ii) the *Revision-Irrelevant Hypothesis*, as the other extreme, that the parser should follow structural preferences like locality even if they lead to make revision, and (iii) the *Intermediate*

Hypothesis that the parser should have a preference for avoiding revision simply as one of the factors involved in its parsing decisions. The target items in (2.5a-d) were used in the first experiment of Sturt, Pickering, Scheepers, and Crocker (2001).

(2.5) a. The troops [who discovered the enemy spy] had shot themselves and were later mentioned in the present report.
b. The troops [who discovered the enemy spy had shot himself] were later mentioned in the present report.
c. The troops [who found the enemy spy] had shot themselves and were later mentioned in the present report.
d. The troops [who found the enemy spy had shot himself] were later mentioned in the present report.

(Sturt, Pickering, Scheepers, & Crocker, 2001: 289, (8a-d), brackets added)

One manipulation was that revision of *the enemy spy* from the object of *discovered*/*found* to the subject of *had* was required in (2.5b, d), but not in (2.5a, c). Another manipulation was that the verb *found* in (2.5c-d) was strongly biased towards the object reading of *the enemy spy*, whereas the verb *discovered* in (2.5a-b) was only weakly biased towards it. Sturt, Pickering, Scheepers, and Crocker (2001) found longer reading times at the reflexive pronoun *himself* in (2.5b, d), compared with *themselves* in (2.5a, c). If the parser follows the locality preference and revises its reading of *the enemy spy* from the object to the subject at *had*, the results would have been reversed. Thus, the results were inconsistent with the *Revision-Irrelevant Hypothesis*. Instead, they were consistent either with RaLR or with the preference for avoiding revision, because they suggest that revision was not attempted prior to the disambiguating reflexive pronoun. The preference for high attachment of *had* to the main clause was replicated in the second and third experiments of Sturt, Pickering, Scheepers, and Crocker (2001). Although the *Revision-as-Last-Resort Hypothesis* was supported, the authors concluded that the *Intermediate Hypothesis* might be more plausible because avoiding revision should be considered no more than one of the factors in parsing decisions.

Counter evidence for RaLR

There is also empirical evidence that can be considered inconsistent with RaLR. The discussion is based on the observation that prosody, which is defined here, for simplicity, as the *length* (or *heaviness*) *of phonological phrasing*, plays a role in overriding RaLR as in (2.6) and (2.7) (Inoue & Fodor, 1995; Hirose, Inoue, Fodor, & Bradley, 1998; Hirose, 1999).

(2.6) sinsetuna gakusei-no imôto
kind student-GEN (younger) sister
a. [kind student]'s sister = sister of kind student
b. kind [student's sister] = kind sister of student
(Inoue & Fodor, 1995: 20, (14))

(2.7) kyokutanni sinsetuna gakusei-no imôto
extremely
a. [extremely kind student]'s sister = sister of extremely kind student
b. [extremely kind] [student's sister] = extremely kind sister of student
(Inoue & Fodor, 1995: 23, (21))

The two strings of words in (2.6) and (2.7) are both *globally ambiguous* because the adjective phrase *(kyokutanni) sinsetuna* ('(extremely) kind') can modify either (a) the linearly local noun *gakusei* ('student') or (b) the linearly non-local noun *imôto* ('sister'), and both readings are grammatical. Based on the assumption of locality in parsing, the local reading (a) should be always preferred. Inoue and Fodor (1995), however, found this to be the case for (2.6) but not for (2.7), where they found a preference for the long adjective phrase's modification of the non-local noun. This suggests that Japanese speakers prefer the non-local reading in the processing of structural ambiguity when the modifier is relatively *prosodically heavy*. This can be interpreted as a violation of RaLR, or as revision from the local reading (a) to the non-local reading (b) that is syntactically not forced, because both readings are grammatical in (2.7). Notice, however, that this interpretation relies on the comprehenders first committing to the local reading (a) even in the processing of (2.7).

Aoshima, Phillips, and Weinberg (2004) presented another piece of evidence that can be considered a violation of RaLR. Two self-paced reading experiments and one sentence completion experiment were conducted to examine whether Japanese comprehenders link a fronted *wh*-phrase either with the embedded verb or with the sentence-final main verb. The target items in (2.8a-b) were used in the first experiment with their respective control counterparts in which the *wh*-phrase is *in situ* (i.e., remaining in its original position) in the embedded clause (the brackets indicate the embedded clause, ACC an ACCusative case marker, DAT a DATive case marker, DECL a DECLarative complementizer, Q a Question particle, and TOP a TOPic marker).

(2.8) a. Dono-seito-ni tannin-wa [kôcyô-ga hon-o yonda-to]
which student-DAT class teacher-TOP [principal-NOM book-ACC read-DECL]
tosyositu-de sisyo-ni îmasita-ka?
library-at librarian-DAT said-Q
'Which student did the class teacher say to the librarian at the library that the principal read a book for?'

b. Dono-seito-ni tannin-wa [kôcyô-ga hon-o yonda-ka]
which student-DAT class teacher-TOP [principal-NOM book-ACC read-Q]
tosyositu-de sisyo-ni îmasita.
library-at librarian-DAT said
'The class teacher said to the librarian at the library which student the principal read a book for.'

(Aoshima, Phillips, & Weinberg 2004 : 30, Table 2)

Importantly for the manipulation, readers can temporarily interpret the fronted dative *wh*-phrase *dono-seito* ('which student') as included either in the main clause or in the embedded clause, although the latter option is forced eventually because another dative NP *sisyo* ('librarian') exists in the main clause. The results showed longer reading times at the embedded verb *yonda* ('read') with a declarative complementizer in (2.8a), compared to the embedded verb with a question particle in (2.8b). According to *filler-driven* parsing (e.g., Fodor, 1978; Crain & Fodor, 1985; Stowe, 1986; Frazier, 1987; Frazier & Clifton, 1989;

Frazier & Flores d'Arcais, 1989), readers should search for the gap site for the sentence-initial *wh*-phrase in the main clause instead of the embedded clause. If the main clause analysis is maintained, longer reading times should be observed at the embedded verb with a question particle in (2.8b), compared to the embedded verb with a declarative complementizer in (2.8a), which is contrary to the experimental results. Thus, the results suggest that Japanese comprehenders preferred the alternative embedded clause analysis to link the fronted dative *wh*-phrase with the embedded verb.[7] This preference was supported in the second and third experiments. Notice that this finding is inconsistent with RaLR because the parser made revision from the initial main clause analysis to the alternative embedded clause analysis for the filler-gap dependency even though it was syntactically not required to do so. This is taken as evidence for unforced revision because the interpretation of the fronted dative *wh*-phrase is temporarily ambiguous at the embedded verb and thus readers are not forced to revise their initial main clause analysis there. Based on the experimental results, Aoshima, Phillips, and Weinberg (2004) concluded that RaLR is too strong to capture all the empirical data, which is consistent with Fodor and Inoue (2000).

Kanamaru, Hirose, and Ito (2009) provided another piece of counterevidence for RaLR. One self-paced reading experiment was carried out using the target items in (2.9a-b) with their baseline controls in (2.9c-d).

[7] Cf. Kamide and Mitchell (1999) for a demonstration of RaLR in Japanese sentence processing. They found that when a dative non-*wh* NP was positioned between the sentence-initial main nominative NP and the embedded nominative NP, it was interpreted as part of the main clause both initially and eventually (i.e., no revision happened).

(2.9) a. Asagohan-no kataduke-ga itumodôri owatta ato-de titioya-ga
breakfast-GEN putting.in.order-NOM as.always finished after father-NOM
hahaoya-ni zibun-no sukâto-o kurôzetto-kara toridasu yôni itta-to
mother-DAT self-GEN skirt-ACC closet-from take to told-that
cyônan-wa hanasita.
oldest.son-TOP said

b. Titioya-ga asagohan-no kataduke-ga itumodôri owatta ato-de
father-NOM breakfast-GEN putting.in.order-NOM as.always finished after
hahaoya-ni zibun-no sukâto-o kurôzetto-kara toridasu yôni itta-to
mother-DAT self-GEN skirt-ACC closet-from take to told-that
cyônan-wa hanasita.
oldest.son-TOP said
'After finishing putting breakfast in order as always, the oldest son said that his father$_i$ told his mother$_j$ to take *his$_i$/her$_j$ skirt from the closet.'

c. Asagohan-no kataduke-ga itumodôri owatta ato-de
breakfast-GEN putting.in.order-NOM as.always finished after
cyôzyo-ga hahaoya-ni zibun-no sukâto-o kurôzetto-kara toridasu
oldest.daughter-NOM mother-DAT self-GEN skirt-ACC closet-from take
yôni itta-to cyônan-wa hanasita.
to told-that oldest.son-TOP said

d. Cyôzyo-ga asagohan-no kataduke-ga itumodôri owatta
oldest.daughter-NOM breakfast-GEN putting.in.order-NOM as.always finished
ato-de hahaoya-ni zibun-no sukâto-o kurôzetto-kara toridasu
after mother-DAT self-GEN skirt-ACC closet-from take
yôni itta-to cyônan-wa hanasita.
to told-that oldest.son-TOP said
'After finishing putting breakfast in order as always, the oldest son said that the oldest daughter$_i$ told his mother$_j$ to take her$_{i/j}$ skirt from the closet.'

(emphasis added)

One manipulation was that revision of the embedded clause from a single clause analysis to a double clause analysis was required at *sukâto* ('skirt') in (2.9a-b), not in (2.9c-d), because without such revision, we would have an unnatural interpretation that the skirt was the father's. This problem did not arise in (2.9c-d) because the oldest daughter was relevant as the owner of the skirt. Another manipulation was the position of the long adjunct (underlined). Due to the long adjunct, revision was predicted to be easier to apply in (2.9b, d), compared to

(2.9a, c). Notice that, in the examples in (2.9a-b), the interpretation of the possessive pronoun was temporarily ambiguous up to the critical region, *sukâto* (‘skirt’). The results showed longer reading times at *sukâto* (‘skirt’) in (2.9a-b), compared to (2.9c-d), and a significant interaction between the two manipulations at the spill-over region (i.e., one region after the critical one), *kurôzetto* (‘closet’), indicating longer reading times in (2.9a), compared to (2.9b). This suggests that revision from the mono-clausal analysis to the bi-clausal analysis of the embedded clause was attempted prior to the critical region in (2.9b) but not in (2.9a). The parser should favor maintaining the simpler mono-clausal analysis for the embedded clause on the assumption of Minimal Attachment (Frazier, 1987). Thus, the observed revision is inconsistent with RaLR, which would require the parser to maintain the mono-clausal analysis because the sentence was temporarily ambiguous up to the critical region. Moreover, Kanamaru, Hirose, and Ito (2009) concluded that because the longer distance between the possessive pronoun and its antecedent (due to the position of the long adjunct) affected the application of revision, RaLR is not an absolute principle in Fodor and Frazier’s sense (1980), but just one of the factors in parsing decisions, as Sturt, Pickering, Scheepers, and Crocker (2001) suggested.

Motivation for the present dissertation

So far, we have reviewed previous studies suggesting that there is both supporting and counter evidence for RaLR. Notice, however, that much of these studies’ empirical evidence has come from the processing of temporarily ambiguous sentences. Due to the nature of temporary ambiguity, one analysis wins the race, and thus revision has to be applied when forced by grammaticality. As observed in the examples of Inoue and Fodor (1995), revision in the processing of (fully) globally ambiguous sentences is particularly important because there is never a syntactic reason to make revision in these cases, and thus we can examine whether the parser will perform unforced revision. Also notice that the supporting evidence for RaLR

has come from English, a head-final language, whereas the evidence against RaLR has been provided by Japanese, a head-final language. This situation suggests the possibility that head-finality could be a key factor in the availability of unforced revision.

The goal of the present dissertation is to provide another piece of evidence that revision can take place when it is syntactically not required by examining relative clause head association ambiguity in Japanese, in which two analyses are both grammatical even at the end of the sentence. Because the target structure is head-final, we will be able to observe such unforced revision if head-finality is a key factor, as previous findings imply.

2.3. Relative Clause Attachment Ambiguity

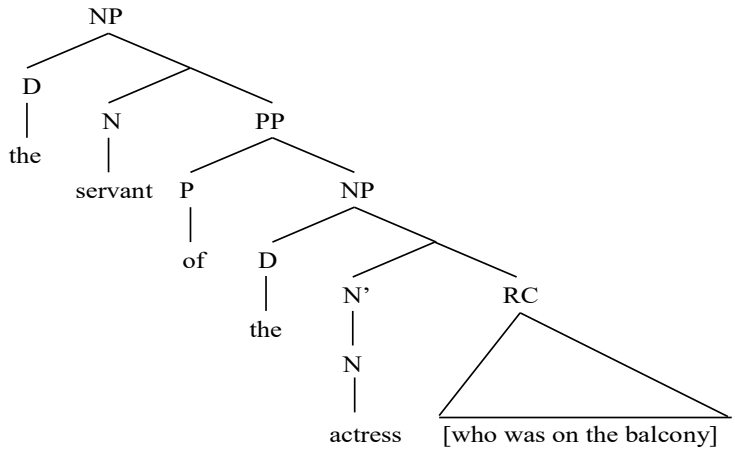
Processing Preferences

The current dissertation focuses on the processing of global structural ambiguity with relative clause (RC) modifiers in Japanese. Because the corresponding phenomenon known as *RC attachment ambiguity* has been examined cross-linguistically, we will review previous studies on it in English in this section. Consider the following example:

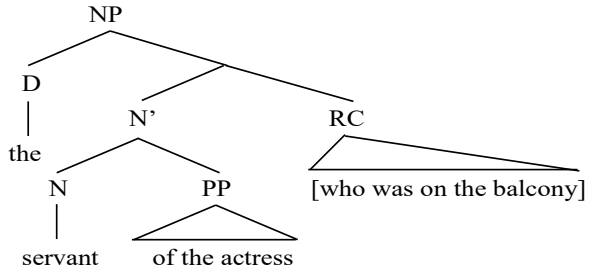
(2.10) Someone shot the servant of the actress [$_{RC}$ who was on the balcony].
(Cuetos & Mitchell, 1988: 95, brackets added)

In (2.10), the RC in brackets can attach either to the structurally low NP *the actress* (i.e., low attachment) as in (2.11a) or to the structurally high NP *the servant* (*of the actress)* (i.e., high attachment) as in (2.11b) (D stands for Determiner, P for Preposition, and PP for Preposition Phrase).

(2.11) a. Low attachment



b. High attachment



The low attachment analysis in (2.11a) means that the person who was on the balcony was the actress, whereas the high attachment analysis in (2.11b) means that the person who was on the balcony was the actress's servant. Note that both structural analyses in (2.11a-b) are grammatical in English (2.10), and thus the ambiguity is global, not temporary. Cuetos and Mitchell (1988) found that English speakers prefer to attach the RC to the structurally low NP, which is consistent with universal locality principles (e.g., *Late Closure*, Frazier, 1979, and its variants, *Recency Preference*, Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996, and *Locality*, Gibson, 1998).[8,9] It was also found, however, that Spanish speakers show the

[8] A similar phenomenon was originally pointed out by Kimball (1973).

[9] Definitions of Late Closure, Recency Preference, and Locality are as follows:

Late Closure: When possible, attach incoming material into the clause currently being parsed. (Frazier, 1979:20)

opposite preference, that is, for high attachment, in the Spanish counterpart of (2.10). This led to many cross-linguistic studies on the processing of RC attachment ambiguity in various languages in order to explicate the nature of parsing (for summaries, see Mitchell, Cuetos, & Zagar, 1990; Cuetos, Mitchell, & Corley, 1996; Mitchell & Brysbaert, 1998; Grillo & Costa, 2014).[10] In these studies, factors other than locality were proposed to explain why in some languages, high attachment is preferred over low attachment. For example, Predicate Proximity (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) and the Main Assertion Principle (Traxler & Frazier, 2008), both of which are extensions of the Relativized Relevance Principle (Frazier, 1990b), explain that the head noun of the complex NP (e.g., *the servant* in *the servant of the actress* in (2.10) above), compared to the adjunct modifier (e.g., *of the actress* in *the servant of the actress* in (2.10)) is more proximate to the main clause verb and more directly contributes to the main assertion, i.e., the content of the main clause, and thus that high attachment is preferred over low attachment in certain pragmatic contexts. Mitchell, Cuetos, and Corley (1992) and Mitchell, Cuetos, Corley, and Brysbaert (1995) accounted for high attachment in terms of linguistic experience. For instance, Mitchell, Cuetos, and Corley (1992) compared the corpus frequency of RC attachment in English and Spanish, and found that the relative frequency of low attachment was higher (62%) in English, whereas the relative frequency of high attachment was higher (60%) in Spanish. These frequency biases in production data are consistent with both English and Spanish speakers' parsing preferences in comprehension data.[11] The results of previous studies are often discussed to evaluate processing accounts, especially the Garden-path and Constraint-based models (see Fernández,

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> *Recency Preference*: Preferentially attach structures for incoming lexical items to structures built more recently.
>
> (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996: 26)
>
> *Locality*: Syntactic predictions held in memory over longer distances are more expensive, and longer distance head-dependent integrations are more expensive.
>
> (Gibson, 1998: 8)

[10] For the comprehensive list of languages examined, see Miyamoto (2008).

[11] Other factors proposed to be involved in high attachment preference include pragmatic effects (e.g., Frazier & Clifton, 1996), prosody (e.g., Fodor, 1998, 2002), and working memory (e.g., Mendelsohn & Pearlmutter, 1999).

2003; Papadopoulou, 2006, for summaries).

Implicit Causality Effects

The phenomenon of RC attachment ambiguity has rarely been discussed in terms of revision. In the context of revision, however, *implicit causality* effects are worth reviewing. Rohde (2008) and Rohde, Levy, and Kehler (2008, 2011) found that the implicit causality between predicates of the main and relative clauses influenced native English speakers' resolution of RC attachment ambiguity. The target items in (2.12a-b) was used by Rohde, Levy, and Kehler (2008) in an off-line sentence completion experiment.

(2.12) a. John *detests* the children of the musician who ….
b. John *babysits* the children of the musician who ….

(emphasis added)

The main verbs (italicized) were manipulated as to whether they trigger implicit causality as in (2.12a) or not as in (2.12b). A verb like *detest* in (2.12a), which triggers implicit causality, strongly searches for its reason in terms of its inherent meaning. On the other hand, a verb like *babysit* in (2.12b) does not necessarily trigger implicit causality. By this manipulation, Rohde, Levy, and Kehler (2008) hypothesized that main verbs triggering implicit causality would increase comprehenders' expectation for high attachment RCs because the head noun for a high attachment RC is an argument required by the main verb. The sentence completion results supported this hypothesis. That is, high attachment RCs were observed more frequently in the implicit causality condition as in (2.12a), compared to the baseline condition as in (2.12b). For example, *are arrogant* was produced for (2.12a) (note that number agreement allowed the experimenter to infer which noun was modified by the RC). These experimental results suggest that the causal relationship between predicates of main and relative clauses may override native English speakers' low attachment preference and

motivate the use of high attachment RCs.

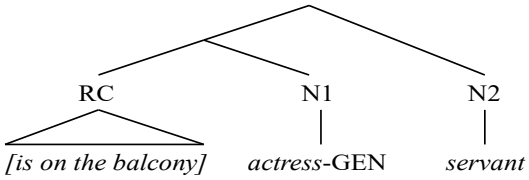
2.4. Head Association Ambiguity in Japanese Relative Clauses

In this section, we review previous studies on the target phenomenon examined in the present dissertation. Several studies have indicated that comprehenders may perform revision in the processing of Japanese RCs such as the one in (2.13) (e.g., Kamide & Mitchell, 1997).

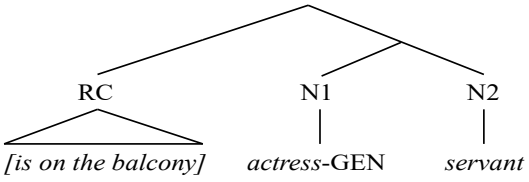
(2.13) [barukonî-ni iru] joyû-no mesitukai
[$_{RC}$ balcony-on is] actress-GEN servant
'the servant of the actress who is on the balcony'
(Kamide & Mitchell, 1997: 249, brackets added)

For this globally ambiguous phrase, the prenominal RC can be associated either with the first potential head noun (N1) *joyû* ('actress') (i.e., N1 association) as in (2.14a) or with the second potential head noun (N2) (*joyû-no*) *mesitukai* ('(actress's) servant') (i.e., N2 association) as in (2.14b) (English glosses are presented in italics).

(2.14) a. N1 association



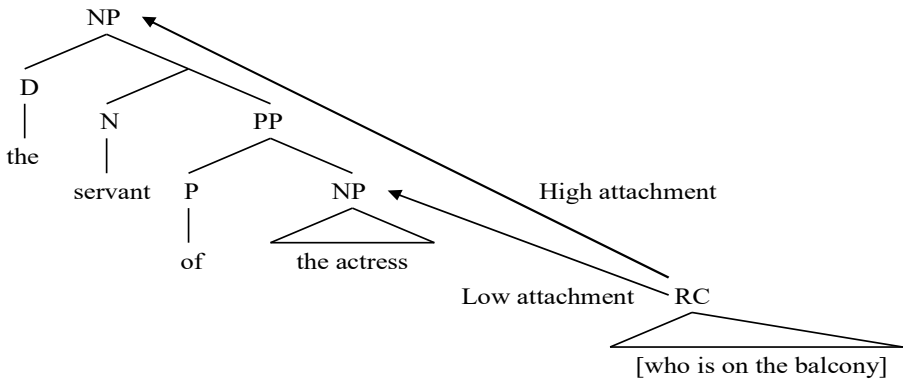
b. N2 association



The N1 association analysis in (2.14a) means that it is the actress who is on the balcony, whereas the N2 association analysis in (2.14b) means that it is the actress's servant who is on the balcony. It is important to note that the structural analyses in both (2.14a-b) are grammatical in Japanese (2.13), and thus that the structural ambiguity is not temporary but global.

This Japanese phenomenon appears to be similar to the English counterpart, but, in fact, is drastically different in terms of incremental parsing. First, we consider the English translation of (2.13). The parser first processes a complex NP, but the following RC produces attachment ambiguity (i.e., high and low attachment analyses are both grammatically possible) as in (2.15).

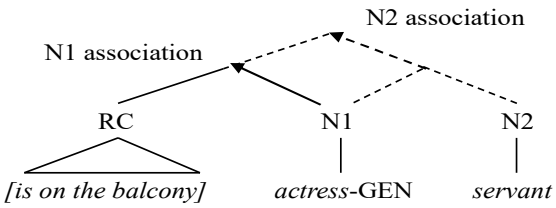
(2.15) *RC attachment ambiguity*



This RC attachment ambiguity in English is not relevant to an examination of the possibility of revision because the two attachment sites are both available prior to the RC as seen in (2.15). To be more concrete, the parser can select high or low attachment at the point of the RC in (2.15) without constructing a syntactic structure for the alternative analysis. On the other hand, in Japanese (2.13), the RC precedes its head noun and the RC does not occur with a relativizer or a special ending on the RC verb. Therefore, the parser first encounters a clause

(i.e., the bracketed one in (2.13)). Second, the occurrence of the N1 signals that the preceding clause is a RC, and at this point, the N1 association analysis is considered. The genitive case marker attached to the N1 indicates that another noun will follow it, and may make the parser expect the structure for the N2. Thus, either at the genitive case marker or at the N2, the parser can consider the N2 association analysis as another grammatically possible option, leading to ambiguity as in (2.16).

(2.16) *Head association ambiguity*



We term this phenomenon *head association ambiguity* or *RC head association ambiguity* instead of *RC attachment ambiguity* as in English. Head association ambiguity in Japanese RC processing is relevant to testing unforced revision in parsing because the two potential head nouns, N1 and N2, both become available after the RC and, more importantly, the N1 association analysis can be considered before the N2 association analysis becomes available. Hence, the possibility of revision to the alternative N2 association analysis is worth examining from the perspective of the Revision as Last Resort hypothesis, which forces the parser to maintain the initial grammatical N1 association analysis.

Previous studies show mixed results for the processing of head association ambiguity in Japanese RCs. For example, in their off-line questionnaire experiment, Kamide and Mitchell (1997) found that Japanese comprehenders preferred the N2 association interpretation. They used exact Japanese translations of the English experimental materials used by Cuetos and Mitchell (1988). The sentence in (2.17) is an example (LOC stands for LOCative case

marker).

(2.17) Dareka-ga [barukonî-ni iru] joyû-no mesitukai-o utta.
someone-NOM [RC balcony-LOC is] actress-GEN servant-ACC shot
'Someone shot the servant of the actress who was on the balcony.'
(Kamide & Mitchell, 1997: 249)

The experimental results showed that Japanese speakers preferred the N2 association interpretation (66%) to the N1 association interpretation (34%). Kamide and Mitchell (1997) also conducted an on-line self-paced reading experiment, in which they manipulated the plausibility of the relationship between the RC and its potential head nouns. In their target items, either the N1 was an implausible head noun for the RC, thus forcing the N2 association analysis, as in (2.18a), or the N2 was the implausible RC head noun, thus forcing the N1 association analysis, as in (2.18b). Kamide and Mitchell (1977) found that Japanese comprehenders experienced greater difficulty in the N1 region in the former case (i.e., when the N1 was an implausible head noun), compared to the latter case (i.e., when the N2 was the implausible RC head noun). (The slashes in the examples mark where the sentence was segmented for self-paced reading.)

(2.18) a. [Hôsekibako-no sumi-ni nokotteita] / hannin / -no / simon / -o /
[RC jewel.box-GEN corner-LOC remained] criminal -GEN fingerprint -ACC
keisatu-ga / nantoka mitukedasita.
police-NOM manage found.out
'The police managed to find out the fingerprint of the criminal that remained in a corner of a jewel box.'

b. [Gozyûdai dansei to suitei sareru] / hannin / -no / simon / -o /
[RC fifties man that assume Passive] criminal -GEN fingerprint -ACC
keisatu-ga / nantoka mitukedasita.
police-NOM manage found.out
'The police managed to find out the fingerprint of the criminal that was assumed to be a man in his fifties.'
(Kamide & Mitchell, 1997: 250, (3)-(4), brackets and slashes added)

The results showed longer reading times at *hannin* ('criminal') and *no* ('GEN'), which were presented separately, when the N1 association analysis is implausible as in (2.18a), compared to (2.18b), in which the N1 association analysis is plausible. Interestingly, the reading times for the sentence-final main predicate region were longer when the N2 association analysis was implausible as in (2.18b) compared to when the N2 association analysis was plausible as in (2.18a). Based on these results, Kamide and Mitchell (1997) concluded that Japanese comprehenders have an initial preference for the N1 association analysis and revise it to the N2 association analysis at the end of the sentence. Their results, however, might reflect an effect of segmentation. Because the genitive case marker was presented separately from the N1, it would have been highly unlikely for readers to consider the N2 association analysis at the N1. To address this issue, Kamide, Mitchell, Fodor, and Inoue (1998) tested the same materials in another self-paced reading experiment, this time presenting the N1 and the genitive case marker together. The results provided weak support for the N1 association preference. This suggests that even if the N1 is presented together with the genitive case marker, there is still a mild preference for the initial N1 association analysis. Miyamoto, Nakamura, and Takahashi (2004) also tested the same materials used by Kamide and Mitchell (1997) in another self-paced reading experiment in which they presented the N1, the genitive case marker, and the N2 together. The results again supported the N1 association preference (see Miyamoto, Gibson, Pearlmutter, Aikawa, & Miyagawa, 1999, for another piece of evidence for the N1 association preference). Following these studies, we assume that when the parser is processing sentences with RC head association ambiguity in Japanese, it will consider the N1 association analysis as soon as it encounters the first possible head noun for the RC.

In sum, the results from on-line self-paced reading experiments tend to support the N1 association preference (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004; Nakano & Kahraman, 2013) while those from off-line questionnaire experiments

support the N2 association preference (e.g., Kamide & Micthell, 1997; Nakano & Kahraman, 2013).[12] These results suggest the possibility, which was discussed by Kamide and Mitchell (1997), that the parser initially considers the N1 association analysis at the N1 and ultimately revises it to the N2 association analysis at the end of the sentence. However, this possibility has not been verified in the previous studies (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004) because they have tested only two conditions, in which readers are forced to adopt either the N1 or the N2 association analysis at the point of the N2 due to the plausibility of the relationship between the RC and its potential head nouns. These studies showed that Japanese comprehenders experienced greater processing difficulty at the N1 when the N1 association analysis is implausible, compared to when the N2 association analysis is implausible. This is clear evidence for the initial consideration of the N1 association analysis immediately upon encountering the N1. However, the experimental design was not relevant to examining the possibility of revision, and thus we still know little about the real-time course of processing that results in the N2 association analysis. How do comprehenders behave when the sentence is globally ambiguous, i.e., when both the N1 and the N2 association analyses are viable at the point of the N2? Do they maintain their initial N1 association analysis? Or do they revise it to the N2 association analysis? The present dissertation examines the time course of the parser's process of revision from the N1 to the N2 association analysis.

[12] For more mixed results, see Hirose, Inoue, Fodor, and Bradley (1998); Aoyama and Inoue (2005); Uetsuki (2006, 2007); Nakano, Hirose, Yamasaki, Liu, and Nishiuchi (2007); Nakano and Nishiuchi (2007); Nakano (2008); Bai, Kobayashi, and Hirose (2014); Bai, Roland, and Hirose (2014). The results suggest that head association preferences in Japanese RC processing are modulated by a variety of factors such as prosody (i.e., short versus long RC), RC types (i.e., subject- versus object-extracted), word order (i.e., canonical versus scrambled), working memory capacity (i.e., low versus high), pragmatic plausibility, segmentation for reading, and indefiniteness of the N1. We will discuss some of these in the chapters to come, but other factors are beyond the scope of this dissertation.

2.5. Summary

In this chapter, we have reviewed earlier studies on three topics that are relevant to this dissertation: (i) revision in sentence parsing, (ii) RC attachment ambiguity, and (iii) head association ambiguity in Japanese RCs. As for (iii), we have pointed out the remaining issue of the time course for the N2 association analysis. The next chapter presents the research questions, which address this issue, and describes the methodology that we will use to answer the questions.

CHAPTER 3

RESEARCH QUESTIONS

3.1. Introduction

The previous studies on head association ambiguity in Japanese relative clause (RC) processing have shown that Japanese comprehenders have an initial preference for the N1 association, which becomes a preference for the N2 association by the end of an ambiguous RC sentence. (3.1) demonstrates the incremental parsing of RC head association ambiguity.

(3.1) a. S
isi-ga syokusinsiteiru
doctor-NOM palpating
'the doctor is palpating'

b. [RC] N1
[isi-ga syokusinsiteiru] syôzyo
doctor-NOM palpating girl
'the girl (that) the doctor is palpating'

c. [RC] N1-GEN
[isi-ga syokusinsiteiru] syôzyo-no
doctor-NOM palpating girl-GEN
'of the girl (that) the doctor is palpating'

d. [RC] N1-GEN N2
[isi-ga syokusinsiteiru] syôzyo-no ani
doctor-NOM palpating girl-GEN brother
'the brother of the girl (that) the doctor is palpating'

e. [RC] N1-GEN N2 V
[isi-ga syokusinsiteiru] syôzyo-no ani-ga
doctor-NOM palpating girl-GEN brother-NOM
waratteiru
laughing
'the brother of the girl (that) the doctor is palpating is laughing'

First, in (3.1a), the parser receives a noun *isi-ga* ('doctor') and a verb *syokusinsiteiru* ('palpating'); at this point, it may construct an analysis of a single sentence (S) with an

unpronounced object, with the meaning that the doctor is palpating someone. Second, in (3.1b), it turns out that a simple S analysis cannot be constructed at the point of the following noun *syôzyo* (‘girl’). The parser has to introduce a new syntactic node and associate this first potential head noun (N1) with the preceding material, leading to the RC analysis shown by the brackets in (3.1b). Third, in (3.1c), based on the genitive case marker attached to the N1, the parser can expect that another noun will follow, and it may construct the structure for the complex NP in advance before receiving the second potential head noun (N2). Fourth, in (3.1d), at the point of the N2 *ani* (‘brother’) or at the genitive case marker preceding it, a second possibility arises that it is also grammatically possible to associate the N2 with the RC. To achieve this, the parser would have to revise the current N1 association analysis by introducing two new syntactic nodes, one for combining the N1 and N2 to form a complex NP and the other for associating this complex NP with the preceding RC. Note that such revision from the N1 association analysis to the N2 association analysis is syntactically not required (i.e., it is *unforced*) because the ambiguity in question is global. Thus, the N1 association analysis is grammatical and can be maintained. Finally, in (3.1e), the parser receives the main predicate (V) and chooses a final interpretation based on the syntactic structure it is currently considering: either the N1 association analysis or the N2 association analysis.

The results of the previous research provided evidence for the parser’s immediate consideration of the N1 association analysis upon encountering the N1 during real-time processing. We still know little, however, about what might follow; that is, the exact time course of the parser’s process of arriving at the N2 association analysis. An interesting question is why the parser might perform the syntactically complex processing necessary to consider the N2 association analysis when it does not have to for grammaticality. At which point of processing does it consider the N2 association analysis and choose the interpretation to which that analysis leads? How does the N2 association differ from the N1 association with respect to the timing of considering the syntactic analysis and establishing the ultimate

interpretation? To address these questions, this dissertation examines four research questions through a series of off-line and on-line experiments and a corpus analysis.

3.2. Research Questions and Methodology

Research Question 1: Can the parser choose the N2 association interpretation based on the coherence of the whole sentence?

The results of earlier studies on head association ambiguity showed an on-line N1 association preference (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004; Nakano & Kahraman, 2013) and an off-line N2 association preference (e.g., Kamide & Mitchell, 1997; Nakano & Kahraman, 2013). These results suggest that the parser considers the N1 association analysis initially, when it encounters the N1, and revises it to the N2 association analysis ultimately, at the end of the sentence. However, it is not clear at what point the parser would perform such revision during on-line processing. One possibility is that revision occurs at the N2, but the previous research has not provided on-line evidence for this. It may also be the case that, after encountering the N2, the parser changes its analysis from the N1 association to the N2 association by considering the coherence of the sentence as a whole. This possibility leads to Research Question 1. The previous studies have already found that Japanese comprehenders show an off-line preference for the N2 association interpretation. Recall that earlier studies on RC attachment ambiguity in English (e.g., Rohde, Levy, & Kehler, 2008) suggested that the relationship between the predicates of main and relative clauses influences comprehenders' ultimate interpretation. Based on these studies' results, Experiment 1 of this dissertation research employed a questionnaire to investigate Japanese comprehenders' off-line preference for RC head association. Using the results of the questionnaire, we newly examined whether the relationship between the two predicates affects the final choice between the two potential head nouns, specifically in order to test the prediction that the N2 association interpretation is preferred more strongly when the predicate

relationship is biased towards it. Chapter 4 reports and discusses the results of Experiment 1.

Research Question 2: Can the parser consider the N2 association analysis prior to the end of the sentence during real-time processing?

Assuming the initial N1 association preference demonstrated in the previous research, we hypothesize that revision from the N1 to the N2 association analysis that is syntactically not required would occur at the N2 or at the genitive case marker attached to the N1. Earlier studies do not provide evidence for such on-line unforced revision because they tested only two conditions, in which readers are forced to adopt the N1 or N2 association analysis at the point of the N2 (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004). Experiment 1 of our study, with its off-line approach, cannot provide evidence regarding whether the N2 association analysis could happen prior to the end of the sentence. Therefore, to test this hypothesis, two on-line eye-tracking reading experiments (Experiments 2 and 3) were carried out. Experiment 2 examined whether the parser considers the N2 association analysis at the N2. If this is the case, processing difficulty should occur when the sentence-final main predicate following the N2 is incompatible with the analysis. Experiment 3 examined whether the parser expects the N2 association analysis in advance at the genitive case marker attached to the N1, that is, before encountering the N2. If this is the case, processing difficulty should occur when the N2 is impossible as the RC head noun. Experiments 2 and 3 are described in detail in Chapter 5.

Research Question 3: Can the parser consider the N1 association analysis at the N1 initially when both the N1 and the N2 association analyses are available at the N2?

Experiments 2 and 3 investigate comprehenders' real-time RC head association at the points of the N1 and the N2 from the perspective of unforced revision. To further examine the possibility of such revision and understand the time course of the N1 and the N2 association

analyses, we need evidence for the parser's initial consideration of the N1 association analysis at the N1 when the N2 association analysis is also syntactically viable. Two on-line experiments (Experiments 4 and 5) were conducted, adopting a post-sentential probe recognition technique. Experiment 4 examined whether the N1 association analysis can be considered when the N2 association analysis is available. If the N1 association analysis is considered prior to the probe recognition task, comprehenders should respond to a word related to the meaning conveyed by the N1 association analysis faster than they respond to a non-related word. Experiment 5 examined whether the N2 association analysis can be considered when the N1 association analysis can be maintained. If comprehenders perform revision from the N1 to the N2 association analysis, they should respond to a word related to the N2 association interpretation faster than they do to a non-related word. The details of Experiments 4 and 5 are described in Chapter 6.

Research Question 4: Do RC production data show a structural frequency bias towards the N2 association?

If we can demonstrate that revision takes place, the question remains of why the parser would perform revision that is syntactically not required (i.e., from the N1 to the N2 association analysis). Earlier studies on RC attachment ambiguity in English (e.g., Mitchell, Cuetos, & Corley, 1992) suggested that frequency can account for comprehenders' attachment preferences. Drawing on such studies' results, we assume that, if the N2 association interpretation is more often intended in production compared to the N1 association interpretation, comprehenders will experience the N2 association more often and thus be more likely to consider the N2 association analysis in their processing. A corpus analysis examined how often the N2 association interpretation is intended in RC production data to investigate whether structural frequency plays a role in triggering unforced revision. Chapter 7 reports and discusses the results.

CHAPTER 4

OFF-LINE QUESTIONNAIRE EXPERIMENT

4.1. Introduction

The goal of the off-line questionnaire experiment is to examine whether the parser can choose the N2 association interpretation based on the coherence of the whole sentence (Research Question 1). The results of previous studies on relative clause (RC) head association ambiguity in Japanese have shown comprehenders' initial preference for the N1 association analysis at the N1 and eventual preference for the N2 association analysis at the end of the sentence. We still, however, do not clearly understand what triggers the change from the N1 to the N2 association analysis. As shown in earlier studies on RC attachment ambiguity in English, the implicit causality relationship between the predicates of main and relative clauses influences comprehenders' attachment preference (e.g., Rohde, Levy, & Kehler, 2008). Based on such findings for English, our experiment newly examines whether the relationship between the two predicates affects Japanese comprehenders' ultimate interpretation in their processing of RC head association ambiguity.

Experiment 1 is the off-line questionnaire experiment that was carried out to examine Research Question 1. The sentence-final main clause verbs were manipulated as to whether their relationship with the RC verb was implicitly "causal" or not. For example, consider the following pair of sentences:

(4.1) a. *Causal condition*

驚いた探偵の助手が黙った。

[Odoroita] tantei-no zyosyu-ga damatta.

[RC surprised.was] detective-GEN assistant-NOM became.silent

'The assistant of the detective who was surprised became silent.'

b. *Neutral condition*

驚いた探偵の助手が料理した。

[Odoroita] tantei-no zyosyu-ga ryôrisita.

[RC surprised.was] detective-GEN assistant-NOM cooked

'The assistant of the detective who was surprised cooked.'

The two conditions in (4.1a-b) are both globally ambiguous. That is, the person who was surprised can be either the detective (i.e., the N1 association interpretation) or the detective's assistant (i.e., the N2 association interpretation), and both interpretations are grammatical. In (4.1a), the relationship between the sentence-final main clause verb and the RC verb is "causal" in that the RC verb *odoroita* ('was surprised') can be the cause and the main clause verb *damatta* ('became silent') its result. Therefore, in this condition, the N2 association interpretation (i.e., that the surprised person became silent) is more plausible than the N1 association interpretation (i.e., that the surprised person and the person who became silent were different). In (4.1b), on the other hand, the relationship between the main clause verb and the RC verb is not causal, and thus both interpretations are equally plausible; we call the "neutral" condition and treat it as the baseline. This manipulation of *Causality* thus creates two experimental conditions: the *causal* condition as in (4.1a) and the *neutral* condition as in (4.1b). We predicted that if the N2 association interpretation is ultimately established by considering the coherence of the whole sentence, comprehenders will choose it more frequently in the *causal* condition and less frequently in the *neutral* condition. In contrast, if comprehenders choose the N2 association interpretation without considering the meaning of the whole sentence, no difference will be observed between the two conditions.

4.2. Experiment 1

4.2.1. Method

Participants

Twenty undergraduate students at the University of Tokyo were paid to participate in this experiment. They were all native speakers of Japanese.

Materials

There were 16 experimental sentences of the same form as in (4.1a-b) (see Appendix A for the full set of experimental items). The syntactic skeleton of the sentences is as follows: *[$_{RC}$ Verb] N1-GEN N2-NOM Verb*. The bracketed RC was always subject-extracted. The lexical items were identical between the two conditions, except for the sentence-final main Verb, as seen in (4.1a-b). The target items were counterbalanced in a Latin square design, yielding two lists so that each participant saw only one of the two conditions for each item and experienced the same number of sentences in each condition. Forty fillers were included so that the target sentences were not presented consecutively. Eight out of the 40 fillers were ambiguous with respect to pronoun interpretation; the participant's responses to the questions accompanying the 32 unambiguous fillers were used to assess his/her comprehension accuracy.

Norming studies

Two norming studies were conducted for the target items. Nine native Japanese speakers, who did not take part in the main experiment, participated. The goal of the first norming study was to ensure that both the N1 and the N2 could be the head noun for the RC. The respondents were asked to evaluate the plausibility of 16 pairs of items similar to the pair in (4.2a-b) on a six-point scale (1: *very implausible* to 6: *very plausible*; see Appendix B for the questionnaire used in the first norming study).

(4.2) a. *N1-association plausibility*
探偵が驚いた。
Tantei-ga odoroita.
detective-NOM surprised.was
'The detective was surprised.'

b. *N2-association plausibility*
助手が驚いた。
Zyosyu-ga odoroita.
assistant-NOM surprised.was
'The assistant was surprised.'

The subjects were the same as the nouns used for the N1 and N2 of the experimental items, and the verbs were the same as the RC verbs of the experimental items. The plausibility of the N1 associations and the N2 associations was evaluated separately. The results showed no difference in head association plausibility between the two nouns in 11 pairs (5.5 for the N1 and 5.6 for the N2); five pairs that included items showing a difference in plausibility were excluded from the experimental materials.

The second norming study was conducted to confirm that the two verbs of main and relative clauses to be used in Experiment 1's materials were considered either "causal" or "neutral." The respondents were asked to evaluate the causal relationship between the 11 pairs of two verbs, as in (4.3a-b), on a six-point scale (1: *non-causal at all* to 6: *very causal*; see Appendix C for the questionnaire used in the second norming study).

(4.3) a. *Causal condition*
「驚いた」 → 「黙った」
"odoroita" → "damatta"
'surprised.was' 'became.silent'

b. *Neutral condition*
「驚いた」 → 「料理した」
"odoroita" → "ryôrisita"
'surprised.was' 'cooked'

The verbs of the RC and main clause to be used in the target items were presented in pairs as in (4.3a-b). The causal relationships between the two verbs in each pair were evaluated separately for the two conditions. The results showed that in the 11 items, the relationship between the verbs was significantly more likely to be judged "causal" in the *causal* condition as in (4.3a) compared to the *neutral* condition as in (4.3b). (The mean scores were 5.7 for the *causal* condition and 1.7 for the *neutral* condition ($p < .001$).)

Procedure

The questionnaire was presented to each participant individually on a PC using Linger software.[13] First, the participant read a sentence as in (4.4), which appeared on the screen.

(4.4) 驚いた探偵の助手が黙った。
Odoroita tantei-no zyosyu-ga damatta.
surprised.was detective-GEN assistant-NOM became.silent
'The assistant of the detective who was surprised became silent.'

Upon finishing reading, the participant pressed the space key and the sentence disappeared. Next, the participant saw a question, which was presented along with two possible answers, as in (4.5).

(4.5) 誰が驚いたか？ 探偵 助手
Dare-ga odoroita ka? tantei zyosyu
who-NOM surprised.was Q detective assistant
'Who was surprised? detective assistant'

The left/right position of the two possible answers was counterbalanced.

The participant was instructed to read the sentences well at a normal pace and answer the accompanying questions without taking too much time. After a six-trial practice session, the

[13] For Linger, see the website: http://tedlab.mit.edu/~dr/Linger/.

main session started. No feedback was given during the task, and no time limit was set. The presentation of the items was randomized for each participant by Linger. Participants took around thirty minutes to complete the experiment.

Data treatment

First, the participants' mean accuracy was calculated by their responses to the comprehension questions of the 32 unambiguous filler sentences.

Second, the mean ratios of the N2 association interpretation in the two conditions were compared by generalized Linear Mixed-Effects (LME) modeling (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). The dependent variable was the choice of the N1 association or the N2 association. *Causality* (*causal* or *neutral*) was the fixed effect, which was centered (i.e., effect coding), and participants and items were the random effects. The best-fit model was chosen by a backward selection approach. The maximal structure consisted of a random intercept and slope of the fixed effect for both participants and items. Estimated coefficients (β), standard errors (*SE*), and *z* and *p* values are reported in Section 4.2.2.[14]

4.2.2. Results

First, the participants' mean comprehension accuracy for the 32 unambiguous fillers was 97.8% (SD = 2.7).

Second, the RC head association results are summarized in Figure 4-1.

[14] The *p* value was calculated automatically by *glmer* in the R package *lme4.0*.

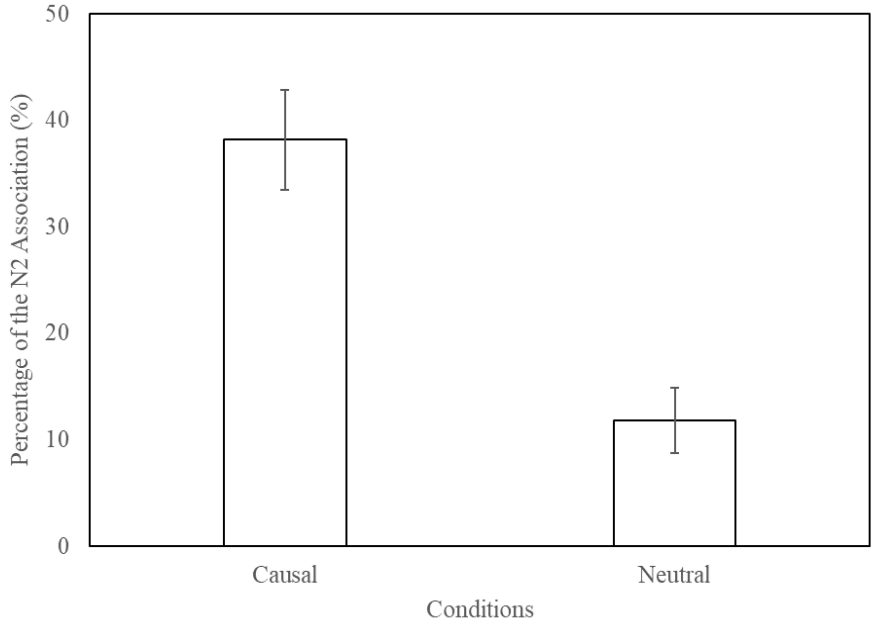


Figure 4-1: The mean ratios of the N2 association in the two conditions (Experiment 1)

Note: The vertical axis stands for the mean ratio of the N2 association in percentage (error bars for SEs) and the horizontal axis for the two conditions.

The mean ratios of the N2 association were 38.2% (SE = 4.7) in the *causal* condition and 11.8% (SE = 3.1) in the *neutral* condition. The best-fit model showed that the mean ratio of the N2 association was significantly higher in the former condition than in the latter condition ($\beta = 0.93$; $SE = 0.20$; $z = 4.76$; $p < .001$). This suggests that the participants chose the N2 association interpretation more frequently when the RC and main clause verbs were causal compared to when they were not. The results also showed the participants' overall preference for the N1 association interpretation (i.e., both percentages in the two conditions were above 50%).

4.3. Discussion

The goal of Experiment 1 was to answer Research Question 1: Can the parser can choose the N2 association interpretation based on the coherence of the whole sentence? The answer is yes. As predicted, the results showed that the participants chose the N2 association interpretation more frequently in the *causal* condition, in which the RC and main clause verbs

were causally related with each other and thus supported the N2 association interpretation, compared to the *neutral* condition, in which the two verbs were not causal. Consider the sentence in (4.6) again as an example of the *causal* condition, in which the main verb is causal to the RC verb.

(4.6) 驚いた探偵の助手が黙った。
[Odoroita] tantei-no zyosyu-ga damatta.
[$_{RC}$ surprised.was] detective-GEN assistant-NOM became.silent
'The assistant of the detective who was surprised became silent.'

Because the N2 is an argument required by the main verb, the N2 association leads to a more reasonable interpretation than the N1 association would when the relationship between the two verbs is causal, as it is in (4.6). This is because the interpretation that the person described by the main verb is identical with the one described by the RC verb (i.e., the N2 association) is preferred from the perspective of semantic/discourse coherence, compared to the interpretation that the persons described by the two verbs are different (i.e., the N1 association). In other words, it is semantically more reasonable to interpret the person who became silent as the one who was surprised rather than as the one who was not surprised.

The results also showed that the participants preferred the N1 association interpretation in both conditions. In the "neutral" condition, the ideal percentages of the N1 and N2 association interpretations would both be 50% if the condition functioned effectively as the baseline. The percentages of the N1 association interpretation were, however, 88.2% in the *neutral* condition and 62.8% even in the *causal* condition. We did not predict this overall bias towards the N1 association interpretation, which is also different from the previous finding that Japanese comprehenders have an off-line preference for the N2 association interpretation (e.g., Kamide & Mitchell, 1997; Uetsuki, 2007; Nakano & Kahraman, 2013). We suspect that the stimuli in the "neutral" condition themselves were already biased towards the N1 association interpretation. For example, consider the following experimental item:

(4.7) 驚いた探偵の助手が料理した。

[Odoroita] tantei-no zyosyu-ga ryôrisita.

[RC surprised.was] detective-GEN assistant-NOM cooked

'The assistant of the detective who was surprised cooked.'

As shown in the previous research, the coherence of the relationship between the main and relative clauses affects comprehenders' ultimate interpretation. In our study's "neutral" condition as in (4.7), the RC and main clause verbs are completely unrelated, and thus seem to link independently with the N1 and N2, respectively. That is, in (4.7), the person who was surprised is the detective, and the one who cooked is his/her assistant. This might have led to the participants' preference for the N1 association interpretation in our "neutral" condition. If this is the case, the participants might have been biased towards the N1 association interpretation even in our "causal" condition.

Experiment 1's major finding is that the percentage of N2 association interpretations in the "causal" condition was significantly higher than in the "neutral" condition, even though both conditions might have been biased towards the N1 association interpretation. If the parser can choose the N2 association interpretation without considering the whole sentence's coherence, no such difference in percentages should be found between the conditions. Hence, the results demonstrate that the parser can choose the N2 association interpretation by taking the meaning of the whole sentence into consideration. The results can, however, be interpreted in various ways. Do comprehenders consider the N1 association initially at the N1, maintain it at the genitive case marker attached to the N1 or at the N2, and reinterpret it to the N2 association at the end of the sentence? Or do they consider the N1 association initially, revise it to the N2 association at the genitive case marker or at the N2, and maintain the changed interpretation at the end of the sentence? We investigate these questions with the on-line experiments presented in Chapter 5.

4.4. Summary

The results of Experiment 1 show that the participants chose the N2 association interpretation more often when the relationship between the verbs of the main and relative clauses was implicitly causal. As discussed above, however, a question remains as to whether the parser can consider the N2 association analysis prior to the end of the sentence. In other words, we have to examine the detailed time course of arriving at the N2 association analysis by observing the real-time processing of head association ambiguity in Japanese RCs. This is the goal of the eye-tracking reading experiments that are described in detail in the next chapter.

CHAPTER 5

ON-LINE EYE-TRACKING READING EXPERIMENTS

5.1. Introduction

This chapter's concern is whether the parser can consider the N2 association analysis prior to the end of the sentence during real-time processing (Research Question 2). Two on-line eye-tracking reading experiments examined whether the parser can consider the N2 association analysis at the N2 (Experiment 2) and at the genitive case marker attached to the N1 (Experiment 3) by manipulating the plausibility of the N2 association analysis at the sentence-final main predicate following the N2 or at the N2 following the genitive case marker. The experiments also investigated whether the rated typicality of the N1 as the RC head noun would affect the parser's willingness to revise the N1 association analysis and consider the N2 association. The two experiments are described in turn in Sections 5.2 and 5.3 below.

5.2. Experiment 2

5.2.1. Introduction

The purpose of Experiment 2 is to examine whether the parser can revise an initial N1 association analysis to consider the N2 association analysis at the N2 when such revision is syntactically not required (i.e., *unforced*). Earlier on-line self-paced reading studies (e.g., Kamide & Mitchell, 1997; Miyamoto, Nakamura, & Takahashi, 2004; Nakano & Kahraman, 2013) have used two conditions in which readers had to adopt either the N1 or the N2 association analysis at the point of the N2, and they clearly showed that the readers had greater processing difficulty at the N1 when the N1 was implausible as the head noun for the

RC, compared to when the N1 was the implausible RC head noun. Based on these previous findings, we assume that Japanese comprehenders consider the N1 association analysis initially upon encountering the N1. The results of the previous studies, however, are difficult to interpret in terms of revision from the initial N1 association analysis to the alternative N2 association analysis because they did not include a baseline condition in which both analyses were available at the N2. Hence, readers were able to consider only one of the two analyses at the N2. In order to examine the real-time course of the N2 association analysis in terms of such unforced revision, we adopt an interaction design for Experiment 2. First, the plausibility of the N2 association analysis at the sentence-final main predicate following the N2 was manipulated as to whether the main predicates were compatible with the meaning conveyed by the N2 association analysis or not. We call this *N2-association Compatibility*. If the parser considers the N2 association analysis at the N2, processing difficulty should occur when the analysis turns out to be incompatible with the main predicate; otherwise, no such difficulty should be observed even when the predicate is incompatible with the N2 association analysis. In addition, the typicality of the N1s as RC head nouns was manipulated as to whether the N1s were rated as "typical" for the N1 association analysis or "neutral" for both N1 and N2 association analyses. We call this *N1-association Typicality*. If the parser tends to retain the initial N1 association analysis when the N1 is typical as the RC head noun, revision should be more likely to occur when the N1 is neutral (i.e., not biased towards the N1 association analysis); otherwise, the relationship between the RC and the N1 should have no influence on comprehenders' willingness to consider the N2 association analysis. These two manipulations were fully crossed, resulting in a 2 (*N2-association incompatible* versus *N2-association compatible*) x 2 (*N1-association neutral* versus *N1-association typical*) design, as seen in the examples below.

(5.1) a. *N2-association incompatible + N1-association neutral noun*
警察が今まさに捜し回っている少年の女友達が刑務所で服役している。
[Keisatu-ga ima masani sagasimawatteiru] syônen-no onna tomodati-ga
[RC police-NOM right now searching for] boy-GEN female friend-NOM
keimusyo-de fukuekisiteiru.
prison-in serving time
'The female friend of the boy whom the police are searching for right now is serving time in prison.'

b. *N2-association incompatible + N1-association typical noun*
警察が今まさに捜し回っている犯人の女友達が刑務所で服役している。
[Keisatu-ga ima masani sagasimawatteiru] hannin-no onna tomodati-ga
[RC police-NOM right now searching for] criminal-GEN female friend-NOM
keimusyo-de fukuekisiteiru.
prison-in serving time
'The female friend of the criminal whom the police are searching for right now is serving time in prison.'

c. *N2-association compatible + N1-association neutral noun*
警察が今まさに捜し回っている少年の女友達がホテルに泊まっている。
[Keisatu-ga ima masani sagasimawatteiru] syônen-no onna tomodati-ga
[RC police-NOM right now searching for] boy-GEN female friend-NOM
hoteru-ni tomatteiru.
hotel-LOC staying
'The female friend of the boy whom the police are searching for right now is staying at a hotel.'

d. *N2-association compatible + N1-association typical noun*
警察が今まさに捜し回っている犯人の女友達がホテルに泊まっている。
[Keisatu-ga ima masani sagasimawatteiru] hannin-no onna tomodati-ga
[RC police-NOM right now searching for] criminal-GEN female friend-NOM
hoteru-ni tomatteiru.
hotel-LOC staying
'The female friend of the criminal whom the police are searching for right now is staying at a hotel.'

In (5.1a-d), both the N1 and the N2 are grammatical and plausible candidates for the head of the preceding RC at the point of the N2. In other words, both the N1 association analysis and the N2 association analysis are viable at the N2. The N2 association analysis, however, would later either become incompatible as in (5.1a-b) or remain compatible as in (5.1c-d) depending

on the contents of the sentence-final main predicates following the N2. For example, in (5.1a-b) the meaning based on the N2 association analysis is incompatible because it is unnatural that the one whom the police are searching for is serving time in prison.[15] In (5.1c-d), on the other hand, the N2 association analysis is compatible because the one whom the police are searching for can plausibly be staying at a hotel. We call the conditions exemplified in (5.1a-b) *N2-association incompatible* and those exemplified in (5.1c-d) *N2-association compatible*. Furthermore, different nouns were used as the N1s in (5.1a, c) and (5.1b, d). Both types of noun are perfectly possible candidates for the RC head because both *syônen* ('boy') and *hannin* ('criminal') can be searched for by the police. However, a criminal as in (5.1b, d) is more likely to be modified by the RC because a criminal is more typical, compared to a boy, as a person who is searched for by the police. On the other hand, a boy as in (5.1a, c) is not particularly typical as a person searched for by the police and thus less likely to be modified by the RC (although the N1 association analysis can still describe a plausible enough situation). We call the latter conditions, as in (5.1a, c), *N1-association neutral* and the former, as in (5.1b, d), *N1-association typical*.

Based on the results of previous studies, we assume that Japanese comprehenders initially consider the N1 association analysis upon encountering the N1 without waiting for further input. Therefore, our predictions concerning the four conditions described above are as follows. First, if comprehenders consider the N2 association analysis at the N2 and maintain it, they should experience difficulty at the main predicate when the predicate is incompatible with the N2 association analysis, as in the *N2-association incompatible* conditions (e.g., 5.1a-b), and no difficulty will occur when it is not, as in the *N2-association compatible* conditions (e.g., 5.1c-d). (We will discuss the issue of lexical differences in the main predicates in Section 5.2.4.) Because the compatibility of the N2 association analysis is made

[15] Note that the sentences in (5.1a-b) are grammatical; the incompatibility is attributable to pragmatic unnaturalness or oddness (although it is possible that the police are searching for someone even when he/she is serving time in prison).

clear immediately after encountering the main predicate, the main effect of *N2-association Compatibility* would be found in an early eye-movement measure at the predicate (eye-movement measures are described in detail in Section 5.2.2). If the parser does not consider the N2 association analysis at all, no such difference should be found. Second, if the N2 association analysis occurs as a result of revision from the N1 association analysis, we can expect that *N1-association Typicality* could affect comprehenders' willingness to consider the N2 association analysis. We therefore predict that if the parser tends to retain the initial N1 association analysis when the N1 is deemed "typical," as in the *N1-association typical* conditions (e.g., 5.1b, d), it would be more likely to perform revision when the N1 is "neutral," as in the *N1-association neutral* conditions (e.g., 5.1a, c). This is presumably because comprehenders only weakly commit to the N1 association analysis when the N1 is not as biased towards it as the "typical" N1 is. If this is the case, the participants should display greater difficulty at the main predicates incompatible with the N2 association analysis in the *N1-association neutral* condition than in the *N1-association typical* condition. No difference should be observed between the other two conditions because both N1 and N2 association analyses are compatible with the main predicate in them. That is, we should observe an interaction of the two manipulations at the main predicate. This interaction would be found in a late eye-movement measure at the main predicate if the parser has to re-revise the RC head noun from the N2 association analysis to the N1 association analysis. On the other hand, if *N1-association Typicality* does not influence comprehenders' willingness to revise their initial N1 association analysis and consider the N2 association analysis, no interaction should occur at the main predicate.

5.2.2. Method

Participants

Twenty-eight undergraduates at the University of Tokyo were paid to participate in Experiment 2. They were all native speakers of Japanese and had normal or corrected-to-normal vision.

Materials

There were 24 experimental sentences (see Appendix D for the full set of experimental items). The syntactic skeleton of the experimental sentences was as follows: *[$_{RC}$ Subject Adverb Verb] N1-GEN N2-NOM Predicate*. These six regions were used as segmentation for the data treatment, as described below. The bracketed RC was consistently object-extracted. In all four conditions, the lexical items were identical for RC Subject, RC Adverb, RC Verb, and N2-NOM, but different for N1-GEN and the main Predicate, as seen in (5.1). The experimental sentences were counterbalanced in a Latin square design, resulting in four lists, so that each participant saw only one condition for each item and the same number of sentences in each of the four conditions. The experimental sentences were interspersed with 48 filler sentences, which never contained relative clauses. True/false comprehension questions followed ten of the filler sentences to help keep the participant's attention on the task.

Norming studies

To evaluate the validity of our conditions, we conducted three norming studies. The first study examined the manipulation of *N2-association Compatibility* for individual items, i.e., it tested whether readers would reject the N2 association interpretation in the *N2-association incompatible* conditions. Ninety-four native Japanese speakers, who did not participate in the eye-tracking experiment, responded to a questionnaire in which they completed a

forced-choice test, which evaluated their head association preference for the target items (see Appendix E for the questionnaire used in the first norming study). Four lists were prepared for the questionnaire. Excluding 29 respondents who chose the N1 association interpretation for all 24 items and one respondent who chose the N2 association interpretation for all items, the results showed that the mean percentages of the choice of the N2 association interpretation were 3.1% in the *N2-association incompatible* + *N1-association neutral* condition, 3.4% in the *N2-association incompatible* + *N1-association typical* condition, 15.9% in the *N2-association compatible* + *N1-association neutral* condition, and 19.3% in the *N2-association compatible* + *N1-association typical* condition. Generalized linear mixed-effects models were used to analyze the data. For statistical modeling, *N2-association Compatibility* (*N2-association incompatible* or *N2-association compatible*) and *N1-association Typicality* (*N1-association neutral* or *N1-association typical*) were entered as two fixed effects, and participants and items were entered as two random effects. Both fixed effects were centered (i.e., effect coding). The best-fit model chosen by a backward selection approach showed a main effect of *N2-association Compatibility* ($\beta = 3.96$, $SE = 0.77$, $z = 5.16$, $p < .001$), indicating that the participants were less likely to choose the N2 association interpretation in the *N2-association incompatible* conditions (6.5% in total) than in the *N2-association compatible* conditions (35.2% in total). This suggests that the participants rejected the N2 association interpretation more often in the *N2-association incompatible* conditions than in the *N2-association compatible* conditions as intended.[16]

[16] As for the relatively low percentages of the N2 association interpretation in both *N2-association compatible* conditions, a possible reason is that the *N2-association incompatible* sentences forced the N1 association interpretation, and thus they may have made the respondents' choice of the N1 association more dominant overall in the norming study. Although we cannot deny this possibility, the results of the norming study showed the participants' preference for the N1 association interpretation when both N1 and N2 association analyses are available (i.e., in the *N2-association compatible* conditions). We found the N1 association interpretation preference even when the N1 was neutral. Recall that the results of Experiment 1 (Chapter 4) also suggest a bias towards the N1 association interpretation that is consistent with the results of this norming study. Notice, however, that both sets of results are different from the previous studies' findings of an off-line preference for the N2 association interpretation.

The second norming study was conducted with a new group of 16 native Japanese speakers, who did not take part in the eye-tracking experiment, in order to examine the manipulation of *N1-association Typicality* for individual items. The respondents completed a questionnaire in which they were asked to rate the typicality of the events represented in the items on a five-point scale from 1 for *not typical at all* to 5 for *very typical* (see Appendix F for the questionnaire used in the second norming study).

(5.2) a. *N1-association neutral noun*
警察が今まさに少年を捜し回っている。
Keisatu-ga ima masani syônen-o sagasimawatteiru.
police-NOM right now boy-ACC searching for
'The police are searching for the boy right now.'

b. *N1-association typical noun*
警察が今まさに犯人を捜し回っている。
Keisatu-ga ima masani hannin-o sagasimawatteiru.
police-NOM right now criminal-ACC searching for
'The police are searching for the criminal right now.'

In (5.2a-b), the two types of noun (i.e., *N1-association neutral* and *N1-association typical*) used for the N1 of the full target items (as in 5.1) function as the direct object, and the RC information of the target items functions as the main clause information. The typicality of events was evaluated separately for the two conditions. An ordinal logistic regression showed that the typicality rating in the *N1-association typical* condition, as in (5.2b), was higher than that in the *N1-association neutral* condition, as in (5.2a) (the overall mean scores were 4.2 for *N1-association typical* nouns and 3.4 for *N1-association neutral* nouns) (β = -1.31, *SE* = 0.14, z = -9.43, $p < .001$). This suggests that the *N1-association typical* nouns are related to the RC context more strongly, and that the *N1-association neutral* nouns are also plausible as the RC head nouns, as intended.

Finally, the third norming study was carried out with a new group of 14 native Japanese speakers, who did not participate in the eye-tracking experiment. The purpose of this norming

study was to avoid the possibility that the N1 association analysis could never be elicited by our target items. Due to the characteristics of the complex NP in question, it is possible to interpret it appositively. Consider (5.3), for example.

(5.3) 犯人の女友達
hannin-no onna tomodati
criminal-GEN female friend
'the female friend of the criminal' or '(someone's) female friend who is a criminal'

The string of words in (5.3) is ambiguous. One interpretation indicates that there are two persons, i.e., a criminal and his/her female friend. The other interpretation, which is an appositive reading, indicates that there is only one person, i.e., someone's female friend who is a criminal. If comprehenders adopt the latter, appositive reading, they will not consider the initial N1 association analysis. Hence, the eye-tracking data from such items could not be interpreted in terms of the parser's initial consideration of the N1 association analysis or the possibility of revision from the N1 to the N2 association analysis. In the norming study, the informants were asked to evaluate the possibility of the appositive reading for complex NPs as in (5.4a-b) on a three-point scale: 1 for appositive reading impossible, 2 for appositive reading possible but not dominant, and 3 for appositive reading dominant (see Appendix G for the questionnaire used in the third norming study). (In (5.4), the second interpretation (underlined) is appositive.)

(5.4) a. 少年の女友達
syônen-no onna tomodati
boy-GEN female friend
'the female friend of the boy' or '(someone's) female friend who is a boy'
b. 犯人の女友達
hannin-no onna tomodati
criminal-GEN female friend
'the female friend of the criminal' or '(someone's) female friend who is a criminal'

The overall mean score was 1.4, suggesting that it would be unlikely for comprehenders to interpret the complex NPs in our target items appositively. This means that our target items made it possible for comprehenders to initially consider the N1 association analysis and make unforced revision.

Procedure

The experiment was carried out individually in a soundproof chamber. The participant sat in front of a computer monitor. The participant's eye movements while reading sentences were recorded by an EyeLink II system (SR Research) at a sampling rate of 500 Hz. The experimenter calibrated the eye-tracker at the beginning of the session, and recalibrated it during the session as required. Participants were instructed to read the sentences well and at a natural pace. At the beginning of each trial, a fixation box appeared near the left edge of the monitor. A brief gaze at the box triggered the presentation of a sentence. After reading a sentence, the participant pressed a button on a game pad (Microsoft Sidewinder), which triggered the presentation of the next trial with a fixation box. When a comprehension question appeared, the participant answered it by pressing either the left or the right button on the game pad.

In the experiment, the participants first went through a practice session with six trials and then the main session with 72 trials. The EyeLink II system presented the trials to each participant in a random order, but in such a way that a participant never saw two target items consecutively. The participant received no feedback. The task was untimed; each experimental session took approximately thirty minutes.

Data treatment

For the analysis of the eye-movement data, the experimental sentences were segmented into six regions: RC Subject, RC Adverb, RC Verb, N1-GEN, N2-NOM, and main Predicate.

The results from four major eye-movement measures (Clifton, Staub, & Rayner, 2007) are reported below: first-pass time (with regressions) (i.e., time spent from first entering a region until leaving that region either to the left or right), regression-path (or go-past) time (i.e., time spent from first entering a region until leaving the region to the right, including fixation durations in the re-reading of earlier regions), second-pass time (i.e., time spent in a region for re-reading after leaving the region to the right), and regressions-out (i.e., whether a reader made a regressive eye-movement to earlier regions or not). Reading times beyond 3 SDs above or below each participant's mean were replaced with the boundary values (overall, approximately less than 2% of the data were thus affected). The data were analyzed using Linear Mixed-Effects (LME) models. For the LME modeling, we entered *N2-association Compatibility* (*N2-association incompatible* or *N2-association compatible*) and *N1-association Typicality* (*N1-association neutral* or *N1-association typical*) as two fixed effects, which were centered (i.e., effect coding), and participants and items as two random effects. The best-fit models were chosen by a backward selection approach. The maximal structure consisted of a random intercept and slope of each fixed effect for both participants and items. The following are reported below: estimated coefficients (β), standard errors (*SE*), *t* values (*z* for regressions-out), and *p* values.[17]

5.2.3. Results[18]

The results for the N1-GEN, N2-NOM, and main Predicate regions are reported in this section.[19] The means (with SEs) of the four measures in each of the three regions are shown in milliseconds for the first-pass, regression-path, and second-pass times and in percentages

[17] *P* values were calculated using the likelihood-ratio test (*p* values for regressions-out were calculated automatically by *glmer* in the R package *lme4.0*). Note that the exact *p* values are reported if they are less than 0.10.

[18] The results reported in this section are from all the participants because the whole group's mean accuracy for comprehension questions was 96.4% (SD = 6.2), and no participant's data were excluded from further analyses.

[19] See Appendix H for the results of the first three regions.

for regressions-out in Table 5.1, and the results from the best-fit LME models are presented in Table 5.2. The results for each of these regions are then discussed in turn.

Table 5-1: The means (and SEs) of four eye-movement measures (Experiment 2)

Measures	N1-GEN *boy/criminal-GEN*	N2-NOM *female friend-NOM*	Main Predicate *prison-in serving time/ hotel-at staying*
First-pass (with regressions)			
N2-association incompatible + N1-association neutral	304 (15)	311 (14)	594 (45)
N2-association incompatible + N1-association typical	375 (16)	337 (14)	553 (39)
N2-association compatible + N1-association neutral	321 (15)	322 (13)	526 (39)
N2-association compatible + N1-association typical	382 (21)	336 (24)	514 (45)
Regression-path			
N2-association incompatible + N1-association neutral	394 (32)	535 (54)	2620 (288)
N2-association incompatible + N1-association typical	463 (44)	553 (48)	3201 (381)
N2-association compatible + N1-association neutral	452 (37)	587 (45)	2917 (379)
N2-association compatible + N1-association typical	503 (39)	510 (46)	2735 (321)
Second-pass			
N2-association incompatible + N1-association neutral	406 (49)	419 (44)	–
N2-association incompatible + N1-association typical	621 (74)	442 (55)	–
N2-association compatible + N1-association neutral	488 (55)	477 (65)	–
N2-association compatible + N1-association typical	557 (69)	364 (47)	–
Regressions-out			
N2-association incompatible + N1-association neutral	13 (3)	28 (5)	79 (4)
N2-association incompatible + N1-association typical	10 (3)	26 (4)	86 (4)
N2-association compatible + N1-association neutral	17 (4)	28 (4)	82 (4)
N2-association compatible + N1-association typical	14 (3)	23 (4)	87 (4)

Note: A hyphen (–) indicates data irrelevant for the sentence-final region.

Table 5-2: The statistical results from the best-fit models for four eye-movement measures (Experiment 2)

Measures	N1-GEN *boy/criminal-GEN*				N2-NOM *female friend-NOM*				Main Predicate *prison-in serving time/ hotel-at staying*			
First-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	344.29	15.79			322.75	15.16			546.68	35.36		
N2Compatibility	9.85	14.29	0.69		7.03	13.50	0.52		-54.04	26.67	-2.03	.04*
N1Typicality	-62.07	22.44	-2.77	.009**	-18.44	13.48	-1.37		27.03	26.67	1.01	
Interaction	11.59	36.23	0.32		10.96	26.96	0.41		-28.06	53.35	-0.53	
Regression-path	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	499.80	29.61			546.82	28.55			2865.01	323.20		
N2Compatibility	44.50	29.36	1.52		6.46	43.02	0.15		-90.86	200.89	-0.45	
N1Typicality	-58.16	45.87	-1.27		30.84	43.00	0.72		-193.71	212.57	-0.91	
Interaction	16.92	58.73	0.29		97.81	85.99	1.14		775.32	311.19	2.49	.013*
Second-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	518.06	56.77			425.65	50.10			–	–		
N2Compatibility	8.45	45.59	0.19		-10.20	45.44	-0.23		–	–	–	–
N1Typicality	-142.17	57.90	-2.46	.017*	45.48	37.55	1.21		–	–	–	–
Interaction	145.32	88.01	1.65		136.50	72.23	1.89	.06†	–	–	–	–
Regressions-out	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
(Intercept)	-2.06	0.19			-1.09	0.15			2.36	0.35		
N2Compatibility	0.17	0.13	1.35		-0.03	0.10	-0.32		0.09	0.12	0.80	
N1Typicality	0.14	0.13	1.10		0.08	0.10	0.81		-0.30	0.12	-2.47	.013*
Interaction	0.01	0.13	0.07		0.06	0.10	0.61		0.03	0.12	0.27	

† p < .1, * p < .05, ** p < .01, *** p < .001

Note: N2Compatibility stands for *N2-association Compatibility* and N1Typicality for *N1-association Typicality*; a hyphen (–) indicates data irrelevant for the sentence-final region.

N1-GEN region (e.g., boy/criminal-*GEN)*

The results of first-pass times in the N1-GEN region (Figure 5-1) showed a main effect of *N1-association Typicality*.

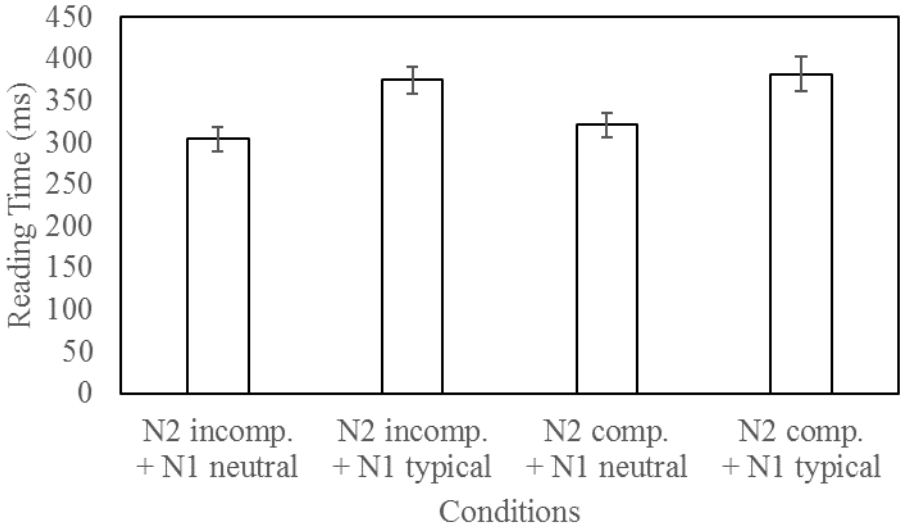


Figure 5-1: The mean first-pass times in the N1-GEN region (Experiment 2)

Note: The vertical axis stands for mean reading times in milliseconds (the error bars for SEs), and the horizontal axis for the four conditions (N2 incomp. + N1 neutral for *N2-association incompatible* + *N1-association neutral*; N2 incomp. + N1 typical for *N2-association incompatible* + *N1-association typical*; N2 comp. + N1 neutral for *N2-association compatible* + *N1-association neutral*; and N2 comp. + N1 typical for *N2-association compatible* + *N1-association typical*). The same holds in the following figures.

This main effect indicates that this region was read more slowly when it included the *N1-association typical* nouns compared to the *N1-association neutral* nouns. The results of second-pass times in the N1-GEN region (Figure 5-2) also showed a main effect of *N1-association Typicality*, suggesting that the participants spent more time in re-reading this region when the *N1-association typical* nouns appeared, compared to the *N1-association neutral* nouns.

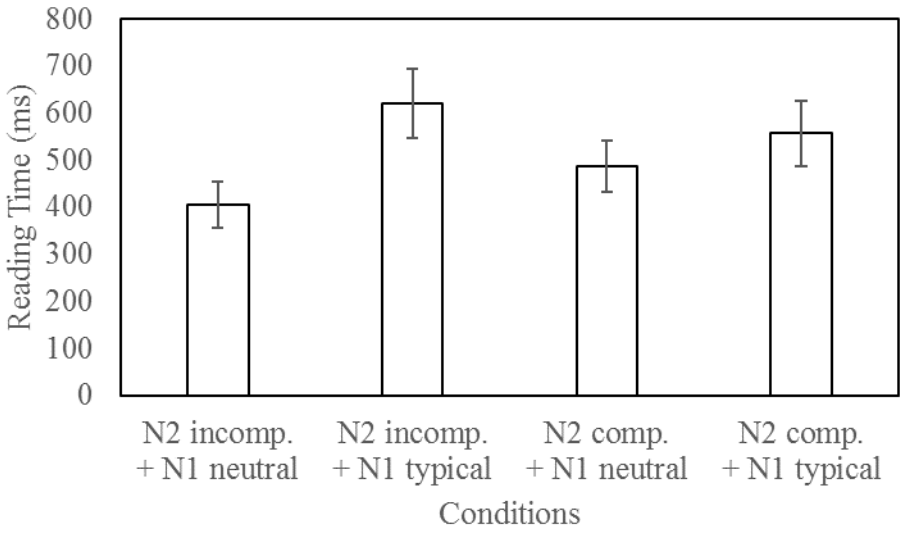


Figure 5-2: The mean second-pass times in the N1-GEN region (Experiment 2)

Because these results were not predicted, we will discuss some possible accounts for them based on the lexical difference between the two types of noun in Section 5.2.4.

N2-NOM region (e.g., female friend-*NOM)*

The results of second-pass times in the N2-NOM region (Figure 5-3) indicated a marginal interaction between *N2-association Compatibility* and *N1-association Typicality* without main effects.

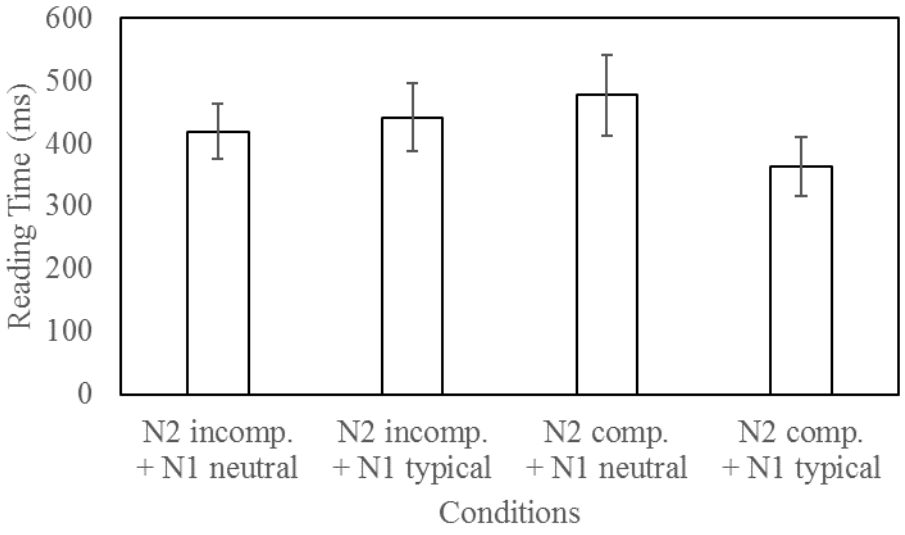


Figure 5-3: The mean second-pass times in the N2-NOM region (Experiment 2)

Further analyses showed that a simple effect of *N1-association Typicality* was significant in the *N2-association compatible* conditions ($\beta = 56.94$, $SE = 25.03$, $t = 2.28$, $p < .05$), suggesting that when the N2 association analysis was compatible with the main predicate, the participants re-read this region more slowly in the *N1-association neutral* condition compared to the *N1-association typical* condition. No simple effect of *N1-association Typicality* was found in the *N2-association incompatible* conditions. We did not predict these results. Because they were observed in the late eye-movement measure, we will discuss a possible account for them considering comprehenders' final choice of the RC head noun in Section 5.2.4.

Main Predicate region (e.g., prison-in serving time/hotel-at staying*)*

The results of first-pass times in the main Predicate region (Figure 5-4) showed that there was a main effect of *N2-association Compatibility*.

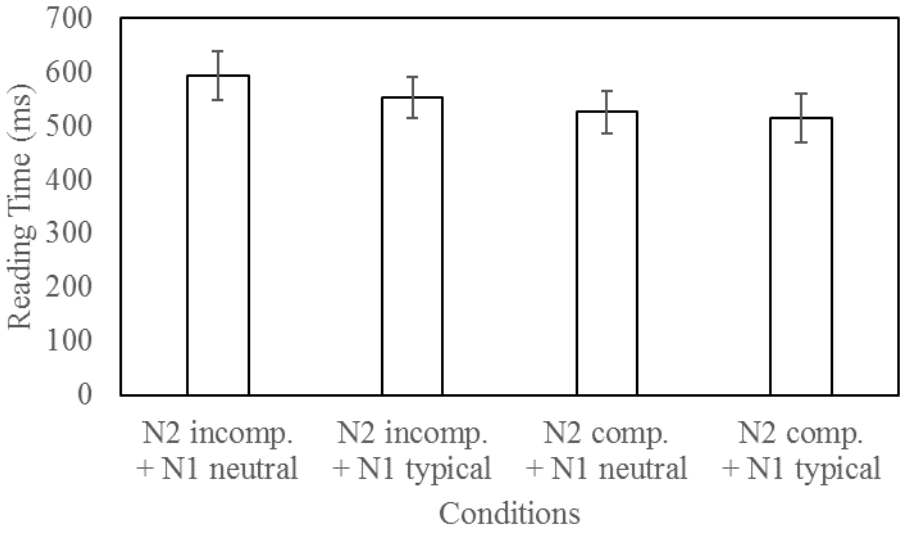


Figure 5-4: The mean first-pass times in the main Predicate region (Experiment 2)

This main effect indicates that the participants took longer to read this region when the N2 association analysis was incompatible with the main predicate compared to when it was not, as we predicted. The results of regression-path times in the main Predicate region (Figure 5-5)

showed that an interaction between *N2-association Compatibility* and *N1-association Typicality* was significant but the main effects were not.

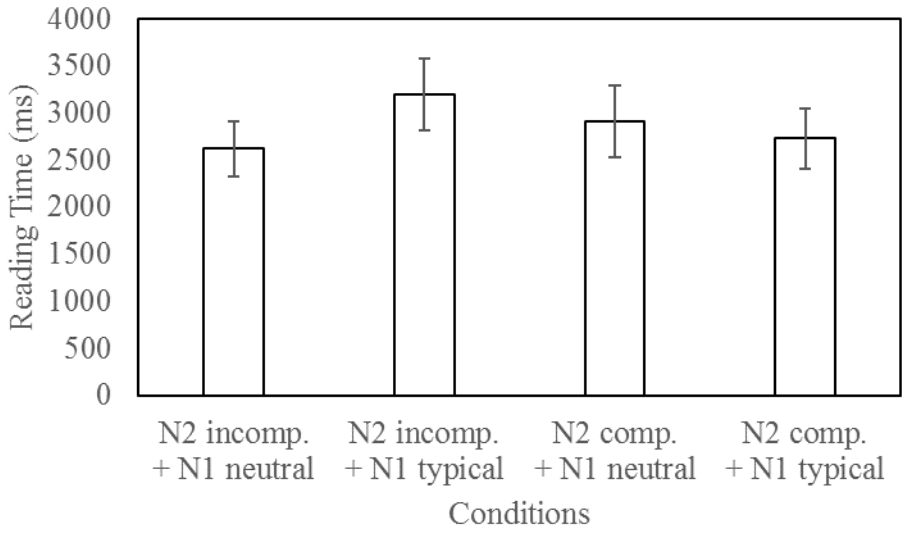


Figure 5-5: The mean regression-path times in the main Predicate region (Experiment 2)

Further analyses showed that a simple effect of *N1-association Typicality* was significant in the *N2-association incompatible* conditions (β = -290.80, *SE* = 140.90, t = -2.06, $p < .05$). This suggests that when the N2 association analysis was incompatible with the main predicate, the participants took longer to read this region in the *N1-association typical* condition compared to the *N1-association neutral* condition. We observed no simple effect of *N1-association Typicality* in the *N2-association compatible* conditions. This pattern of interaction was opposite to our prediction. We will discuss some possible accounts for it based on the results of a post-hoc norming study in Section 5.2.4. The results of regressions-out in the main Predicate region (Figure 5-6) showed a main effect of *N1-association Typicality*.

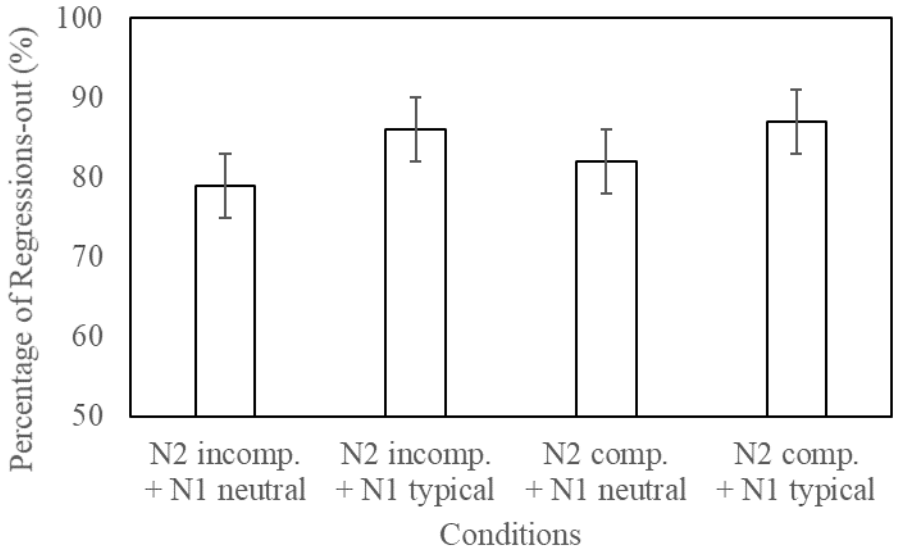


Figure 5-6: The mean ratios of regressions-out in the main Predicate region (Experiment 2)
Note: The vertical axis stands for the mean regressions-out in percentages (the error bars for SEs), and the horizontal axis for the four conditions.

This main effect indicates that the participants made more regressive eye-movements in the *N1-association typical* conditions than in the *N1-association neutral* conditions. Because we did not predict these results, we will discuss them considering the typicality of the N1s in Section 5.2.4.

5.2.4. Discussion

In Experiment 2, we examined whether comprehenders can consider the N2 association analysis at the N2. The finding of a main effect of *N2-association Compatibility* with first-pass reading times in the main Predicate region confirmed our first prediction: the participants showed longer reading times when the sentence-final main predicate following the N2 was incompatible with the N2 association analysis compared to when it was not. As we predicted, this main effect was found in the early eye-movement measure. These findings suggest that the parser had already considered the N2 association analysis prior to the end of the sentence (i.e., at the latest at the N2). There are however, some alternative accounts for this main effect. One is based on the fact that the lexical items used for the main predicates

were different between the *N2-association incompatible* and the *N2-association compatible* conditions, which leads to the possibility that the main effect of *N2-association Compatibility* is due to some difference in those lexical items, such as frequency. To examine this possibility, we searched for the lexical items used in the two conditions in Amano and Kondo's (2000) corpus study, which reported 344,771 words for type frequency and 287,792,797 words for total token frequency in the Asahi newspapers from 1985 to 1998. According to their frequency count, the mean number of occurrences of the adverbs used in the *N2-association incompatible* conditions was higher, at 18,505, than the mean number of occurrences of the adverbs used in the *N2-association compatible* conditions, at 6,122. The mean number of occurrences of the verbs used in the *N2-association incompatible* conditions was also higher, at 9,229, than that of the verbs used in the *N2-association compatible* conditions, at 4,166.[20] Thus, the reading time difference cannot be reduced to the difference in frequency, which would predict the opposite pattern. Another alternative account is based on the relationship between the content of the RC and the main clause. Due to our manipulation, the main clause predicates are harder for the parser to expect based on the RC information in the *N2-association incompatible* conditions compared to the *N2-association compatible* conditions, regardless of whether comprehenders consider the N1 or the N2 association analysis. Hence, a possibility remains that it was this difference that resulted in the main effect of *N2-association Compatibility*.[21]

[20] The occurrences of the words in question were counted only when those words were found in Amano and Kondo's (2000) corpus study.

[21] To check this possibility, the main adverb and verb regions were analyzed separately because the main adverb information in the *N2-association incompatible* conditions alone could be sufficient to indicate the incompatibility of the N2 association analysis (see Appendix D). The separate results for the first-pass times in the main adverb and main verb regions showed the same pattern of *N2-association Compatibility* as the results for the main predicate as a whole (all *t*s > 2). Because the main adverbs are not hard to expect from the RC information for some items, these results may support our interpretation that the parser considered the N2 association analysis prior to the main adverb or the predicate as a whole, suggesting that it is unlikely that the main effect was caused only by the differences in the relationship of the RC and the main clause between the *N2-association incompatible* and the *N2-association compatible* conditions.

As for our second prediction, the results from regression-path reading times in the main Predicate region showed a significant interaction between *N2-association Compatibility* and *N1-association Typicality* (without main effects). Further analyses revealed that when the N2 association analysis became incompatible with the main predicate, the participants showed longer reading times in the *N1-association typical* condition than in the *N1-association neutral* condition. No difference was found when the main predicate was compatible with the N2 association analysis.[22] As predicted, a significant interaction of the two manipulations was observed in the late eye-movement measure. The pattern of interaction was, however, not consistent with our prediction. We predicted that when the main predicate was incompatible with the N2 association analysis, we would observe greater difficulty at the main predicate in the *N1-association neutral* condition than in the *N1-association typical* condition. This prediction was based on the assumption that comprehenders would have a weaker commitment to the N1 association analysis in the *N1-association neutral* condition than in the *N1-association typical* condition and thus be more likely to perform revision in the former. The results were opposite to our prediction.

A possible alternative account, though it seems counter-intuitive, is that the parser commits to the initial N1 association analysis at the N1 more strongly and then to the alternative N2 association analysis at the N2 more strongly in the *N1-association typical* condition than in the *N1-association neutral* condition (i.e., it considers the N2 association analysis at the N2 more strongly in the former condition). If so, it would be because, for example, it is more likely that the police are searching for a criminal's female friend, rather than a boy's female friend, and thus comprehenders consider the N2 association analysis more strongly in the *N1-association typical* condition. If this is the case, it would be more difficult

[22] The main adverb and verb regions were analyzed separately (see footnote 21). The results from the main adverb region showed the same pattern of interaction for the regression-path and second-pass times and regressions-out (all *t*s > 2). The results from the main verb region also showed the same pattern of interaction for the regression-path times ($t = 1.88$). These results support our findings in the sentence-final main Predicate region, possibly mitigating the concern that the results reflect a "wrap-up" effect.

to suppress the N2 association analysis when it becomes incompatible at the main predicate in the *N1-association typical* condition, compared to the *N1-association neutral* condition. This account is consistent with the results of our first norming study on the RC head association preference in the experimental sentences, such as those in (5.1a-d), which are repeated here as (5.5a-d).

(5.5) a. *N2-association incompatible + N1-association neutral noun*
警察が今まさに捜し回っている少年の女友達が刑務所で服役している。
[Keisatu-ga ima masani sagasimawatteiru] syônen-no onna tomodati-ga
[RC police-NOM right now searching for] boy-GEN female friend-NOM
keimusyo-de fukuekisiteiru.
prison-in serving time
'The female friend of the boy whom the police are searching for right now is serving time in prison.'

b. *N2-association incompatible + N1-association typical noun*
警察が今まさに捜し回っている犯人の女友達が刑務所で服役している。
[Keisatu-ga ima masani sagasimawatteiru] hannin-no onna tomodati-ga
[RC police-NOM right now searching for] criminal-GEN female friend-NOM
keimusyo-de fukuekisiteiru.
prison-in serving time
'The female friend of the criminal whom the police are searching for right now is serving time in prison.'

c. *N2-association compatible + N1-association neutral noun*
警察が今まさに捜し回っている少年の女友達がホテルに泊まっている。
[Keisatu-ga ima masani sagasimawatteiru] syônen-no onna tomodati-ga
[RC police-NOM right now searching for] boy-GEN female friend-NOM
hoteru-ni tomatteiru.
hotel-LOC staying
'The female friend of the boy whom the police are searching for right now is staying at a hotel.'

d. *N2-association compatible + N1-association typical noun*
警察が今まさに捜し回っている犯人の女友達がホテルに泊まっている。
[Keisatu-ga ima masani sagasimawatteiru] hannin-no onna tomodati-ga
[RC police-NOM right now searching for] criminal-GEN female friend-NOM
hoteru-ni tomatteiru.
hotel-LOC staying
'The female friend of the criminal whom the police are searching for right now is staying at a hotel.'

The results showed that the mean ratios of the N2 association interpretation were 3.1%, 3.4%, 15.9%, and 19.3% in the conditions exemplified in (5.5a-d), respectively. Interestingly, we found a significant interaction of the two manipulations ($\beta = 4.13$, $SE = 1.69$, $z = 2.45$, $p < .05$). Although a simple effect of *N1-association Typicality* was not significant in the

N2-association compatible conditions (p = .642), the results imply that the N2 association interpretation was chosen numerically more often in the *N2-association compatible* + *N1-association typical* condition as in (5.5d) compared to the *N2-association compatible* + *N1-association neutral* condition as in (5.5c) (19.3% in the former and 15.9% in the latter). The results may be consistent with the above account that comprehenders commit to the N2 association analysis more strongly, and thus choose it as the final interpretation more often, in the former condition than in the latter condition. This account may be consistent with the results from the regressions-out measure in the main predicate region. They showed a main effect of *N1-association Typicality*, indicating that the participants made regressive eye-movements more often in the *N1-association typical* conditions compared to the *N1-association neutral* conditions. A stronger commitment to the N2 association analysis in the former conditions, leading to greater difficulty when the N2 association analysis turned out to be incompatible at the main predicate, could explain this behavior.

This alternative account would predict higher typicality ratings for events described by the N2 association analysis in the *N1-association typical* conditions than in the *N1-association neutral* conditions. To examine this prediction, a post-hoc norming study was carried out with 57 native Japanese speakers who had not taken part in the eye-tracking experiment. Each item appeared in four conditions, as in (5.6a-d).

(5.6) a. *N1-association neutral noun*
警察が今まさに少年を捜し回っている。
Keisatu-ga ima masani syônen-o sagasimawatteiru.
police-NOM right now boy-ACC searching for
'The police are searching for the boy right now.'

b. *N1-association neutral noun + GEN + N2*
警察が今まさに少年の女友達を捜し回っている。
Keisatu-ga ima masani syônen-no onna tomodati-o sagasimawatteiru.
police-NOM right now boy-GEN female friend-ACC searching for
'The police are searching for the female friend of the boy right now.'

c. *N1-association typical noun*
警察が今まさに犯人を捜し回っている。
Keisatu-ga ima masani hannin-o sagasimawatteiru.
police-NOM right now criminal-ACC searching for
'The police are searching for the criminal right now.'

d. *N1-association typical noun + GEN + N2*
警察が今まさに犯人の女友達を捜し回っている。
Keisatu-ga ima masani haninin-no onna tomodati-o sagasimawatteiru.
police-NOM right now criminal-GEN female friend-ACC searching for
'The police are searching for the female friend of the criminal right now.'

The respondents were asked to evaluate the typicality of the events in the experimental sentences on a five-point scale from 1 for *not typical at all* to 5 for *very typical* (see Appendix I for the questionnaire used in this norming study). The mean scores for sentences like (5.6b) and (5.6d) were 3.3 and 3.2, respectively, showing no significant difference (the scores for the other conditions did indicate a significant difference; see the discussion of the second norming study in Section 5.2.2). This finding suggests that the event typicality of the N2 association analysis was not dependent on *N1-association Typicality*. Although event typicality and the probability of the parser's considering the N2 association analysis in processing are not the same, the results of the post-hoc norming study are not consistent with our prediction based on the alternative account.

A remaining possibility is that our manipulation of *N1-association Typicality* did not work as we predicted. If the parser is more likely to perform revision due to its weaker commitment

to the N1 association analysis when the N1 is neutral, longer reading times should be found at a main predicate that is incompatible with the N2 association analysis in the *N1-association neutral* condition than in the *N1-association typical* condition. Only seven out of 24 experimental items were (numerically) consistent with our prediction in this way. On the other hand, the other items showed the opposite pattern of interaction: (numerically) longer reading times at a main predicate incompatible with the N2 association analysis in the *N1-association typical* condition compared to the *N1-association neutral* condition. Because no systematic patterns can be found in these two groups of items, we cannot assume that our manipulation of *N1-association Typicality* is reliable. Hence, it is difficult to interpret the results of the interaction observed in the main predicate in terms of unforced revision from the N1 to the N2 association analysis.

The results from first-pass and second-pass reading times in the N1-GEN region showed a main effect of *N1-association Typicality* (without a main effect of *N2-association Compatibility* or an interaction of the two manipulations). These results suggest that the participants experienced greater difficulty in this region in the *N1-association typical* conditions compared to the *N1-association neutral* conditions. According to Amano and Kondo's (2000) frequency counts, the nouns used in the *N1-association typical* condition were less frequent than those used in the *N1-association neutral* condition (the mean occurrences were 5,123 for the former nouns and 12,637 for the latter nouns, out of 287,792,797 words for the total token frequency).[23] Hence, this reading time difference can be attributed to the difference in frequency. Another possible account is that a difference in the types of noun used for the neutral and typical N1s may have led to the main effect of *N1-association Typicality*. In our items (see Appendix D), the nouns used for the typical N1s (e.g., *hannin* 'criminal') are semantically more specific and thus may require a longer time to process, compared to those used for the neutral N1s (e.g., *syônen* 'boy'). This varying

[23] For lexical frequency, see footnote 20.

specificity may also be involved in the observed main effect. Both accounts are related to lexical properties of the N1s, not to the integration of the RC and the N1.

Finally, the results for the second-pass reading times in the N2-NOM region indicated a marginally significant interaction of the two manipulations (without main effects). This finding suggests that when the N2 association analysis was compatible at the main predicate, the participants took longer to re-read this region in the *N1-association neutral* condition than in the *N1-association typical* condition. We did not predict these results; they might imply that the participants experienced greater difficulty when the N1 and N2 association analyses were both compatible at the main predicate and the N1 was neutral for the N1 association analysis compared to when both analyses were compatible and the N1 was typical for the N1 association analysis. The difference in difficulty would most likely be related to the disambiguation cost. That is, the typical N1s may have facilitated the disambiguation process, resulting in the shorter reading times in the *N1-association typical* condition. The same pattern of interaction was also observed for the second-pass reading times in the RC verb region (see Appendix H). Because the RC verb can inform comprehenders' choice of RC head noun, these results may reflect their disambiguation process. The fact that these results were found in the late eye-movement measure (i.e., the second-pass reading times) may also support this disambiguation account.

In sum, the results suggest that the parser can consider the N2 association analysis prior to the end of the sentence (i.e., at the latest at the N2) during real-time processing. The results of a significant interaction in the main Predicate were suspect, as we discussed, and thus a question remains as to whether the parser initially considers the N1 association analysis before considering the N2 association analysis. In order to further investigate the time course of the N2 association analysis, Experiment 3 examined whether the parser can consider the N2 association analysis even at the genitive case marker attached to the N1, prior to encountering the N2.

5.3. Experiment 3

5.3.1. Introduction

Experiment 3 manipulated the plausibility of the N2 association analysis at the N2 and examined whether comprehenders can consider the N2 association analysis even before encountering the N2. This question is based on the possibility that the parser could expect the N2 association analysis upon encountering the genitive case marker attached to the N1, which signals that another noun will follow. First, the RC verbs and the N2s were newly manipulated as to whether the N2s were lexico-semantically possible as the RC head nouns in terms of animacy. We call this *N2-association Possibility*. In addition, the typicality of the N1 as the RC head noun was manipulated as in Experiment 2, which we call *N1-association Typicality*.[24] These two manipulations were fully crossed, resulting in a 2 (*N2-association impossible* versus *N2-association possible*) x 2 (*N1-association neutral* versus *N1-association typical*) design, as seen in the following examples.

[24] As discussed in regard to Experiment 2, the manipulation of *N1-association Typicality* did not work. The use of different lexical items for the N1s would therefore improve these experiments; however, the same lexical items were used in Experiment 3 because both experiments were conducted at the same time.

(5.7) a. *N2-association impossible + N1-association neutral noun*
警察が今まさに捜し回っている少年の性格がワイドショーで取り上げられた。
[Keisatu-ga ima masani sagasimawatteiru] syônen-no seikaku-ga
[RC police-NOM right now searching for] boy-GEN character-NOM
waidosyô-de toriagerareta.
TV gossip show-in taken up
'The character of the boy that the police were searching for right now was taken up in the TV gossip show.'

b. *N2-association impossible + N1-association typical noun*
警察が今まさに捜し回っている犯人の性格がワイドショーで取り上げられた。
[Keisatu-ga ima masani sagasimawatteiru] hannin-no seikaku-ga
[RC police-NOM right now searching for] criminal-GEN character-NOM
waidosyô-de toriagerareta.
TV gossip show-in taken up
'The character of the criminal that the police were searching for right now was taken up in the TV gossip show.'

c. *N2-association possible + N1-association neutral noun*
警察が今まさに注目している少年の性格がワイドショーで取り上げられた。
[Keisatu-ga ima masani cyûmokusiteiru] syônen-no seikaku-ga
[RC police-NOM right now paying attention to] boy-GEN character-NOM
waidosyô-de toriagerareta.
TV gossip show-in taken up
'The character of the boy that the police were paying attention to right now was taken up in the TV gossip show.'

d. *N2-association possible + N1-association typical noun*
警察が今まさに注目している犯人の性格がワイドショーで取り上げられた。
[Keisatu-ga ima masani cyûmokusiteiru] hannin-no seikaku-ga
[RC police-NOM right now paying attention to] criminal-GEN character-NOM
waidosyô-de toriagerareta.
TV gossip show-in taken up
'The character of the criminal that the police were paying attention to right now was taken up in the TV gossip show.'

In the case of the sentences in (5.7), the inanimate N2 *seikaku* ('character') cannot be "searched for" (a-b), but it can be "paid attention to" (c-d). We call the former conditions, as in (5.7a-b), *N2-association impossible* and the latter conditions, as in (5.7c-d), *N2-association possible*. As in Experiment 2, the nouns used for the N1s in (5.7b, d) are semantically typical

as the RC head for the N1 association analysis, and those in (5.7a, c) are not semantically typical as the RC head for the N1 association analysis but "neutral" for both N1 and N2 association analyses. We call the conditions (5.7b, d) *N1-association typical* and the conditions (5.7a, c) *N1-association neutral*. It is important to note that in Experiment 2, the N1 and N2 were both lexico-semantically possible as the head noun for the RC in all four conditions. In Experiment 3, on the other hand, the N1 is possible as the RC head noun in all four conditions, while the N2 is impossible as the RC head in the *N2-association impossible* conditions but possible in the *N2-association possible* conditions.

Given these four conditions, our predictions are as follows. First, if comprehenders expect (or consider) the N2 association analysis in advance at the genitive case marker attached to the N1, they should experience difficulty at the N2 in the *N2-association impossible* conditions (5.7a-b), but not in the *N2-association possible* conditions (5.7c-d). Because in the former conditions, the N2 association analysis turns out to be impossible upon receiving the N2, this main effect of *N2-association Possibility* would be observed in an early eye-movement measure. If comprehenders do not expect the N2 association analysis at all, no such processing difficulty should be observed. Second, if unforced revision from the initial N1 association analysis is involved, it is conceivable that *N1-association Typicality* will affect comprehenders' expectation of the N2 association analysis. As discussed, the effectiveness of this manipulation is suspect, but we may find some difference at the N2s that are impossible as RC head nouns between the N1-*association neutral* condition (5.7a) and the *N1-association typical* condition (5.7b). No difference should be found between the other two conditions because the N1 and N2 association analyses are both viable. Thus, we may find an interaction of the two manipulations. Any such interaction, however, cannot be attributed to the manipulation of *N1-association Typicality* (i.e., not attributable to the parser's initial commitment to the N1 association analysis), because this manipulation does not work as we intended. Therefore, we will discuss the experimental results mainly based on the

manipulation of *N2-association Possibility*.

5.3.2. Method

Participants

A new group of 28 undergraduates at the University of Tokyo were paid to take part in Experiment 3. They were all native Japanese speakers and had normal or corrected-to-normal vision.

Materials, procedure, and data treatment

The same materials, eye-tracking procedure, and LME modeling for data treatment as in Experiment 2 were adopted. Because the new manipulation was *N2-association Possibility*, the lexical items were identical across the four conditions for RC Subject, RC Adverb, N2-NOM, and the main Predicate while they were different for RC Verb and N1-GEN as seen in (5.7) above (see Appendix J for the full set of experimental items).

Norming studies

Because Experiment 3's materials employed lexical items for the RC verbs and N2s that were different from those in Experiment 2, two norming studies were carried out to check the validity of the two manipulations. One norming study examined whether *N2-association Possibility* works (as well as *N1-association Typicality*). The participants were 32 native Japanese speakers who did not participate in the eye-tracking experiment. They evaluated the event typicality of items in four conditions as in (5.8a-d), which were separated into four lists, on a five-point scale from 1 for *not typical at all* to 5 for *very typical* (see Appendix I for the questionnaire, which is the same as that used in the post-hoc norming study for Experiment 2 discussed in Section 5.2.4).

(5.8) a. *N1-association neutral noun*
警察が今まさに少年を捜し回っている。
Keisatu-ga ima masani syônen-o sagasimawatteiru.
police-NOM right now boy-ACC searching for
'The police are searching for the boy right now.'

b. *N1-association neutral noun + GEN + N2-association impossible noun*
警察が今まさに少年の性格を捜し回っている。
Keisatu-ga ima masani syônen-no seikaku-o sagasimawatteiru.
police-NOM right now boy-GEN character-ACC searching for
'The police are searching for the character of the boy right now.'

c. *N1-association typical noun*
警察が今まさに犯人を捜し回っている。
Keisatu-ga ima masani hannin-o sagasimawatteiru.
police-NOM right now criminal-ACC searching for
'The police are searching for the criminal right now.'

d. *N1-association typical noun + GEN + N2-association impossible noun*
警察が今まさに犯人の性格を捜し回っている。
Keisatu-ga ima masani hannin-no seikaku-o sagasimawatteiru.
police-NOM right now criminal-GEN character-ACC searching for
'The police are searching for the character of the criminal right now.'

The RC information of the target items in (5.7) functions as the main clause information in (5.8a-d). The two types of noun (i.e., *N1-association neutral* and *typical*) used for the N1s of the target items in (5.7) function as the direct objects in (5.8a, c) and as the adjuncts to the N2 in (5.8b, d). The results showed no significant difference in the mean scores for the two types of sentences with the *N2-association impossible* nouns, as in (5.8b) and (5.8d), which were 1.7 and 1.8, respectively. This finding indicates that the inanimate N2s were very unlikely to be considered plausible nouns as the objects of the RC verbs. In other words, in the *N2-association impossible* conditions, the N2 association analysis is very difficult to adopt, as intended. On the other hand, the mean scores for the other two types of sentences, as in (5.8a) and (5.8c), were 4.0 and 4.5, respectively, and the difference was statistically significant ($p < .05$). This suggests that the typical N1s, as in (5.8c), are related to the RC information more strongly compared to the neutral N1s, as in (5.8a), as we intended (although *N1-association*

Typicality is suspect to interpret the results).

The second norming study examined whether *N1-association Typicality* works (as well as *N2-association Possibility*). (Note that, to reiterate, *N1-association Typicality* was not a reliable manipulation.) A new group of 30 native speakers of Japanese was asked to evaluate the event typicality of four conditions as in (5.9a-d), which were presented in four lists, on the same five-point scale (see Appendix I for the questionnaire, which is the same as that used in the post-hoc norming study for Experiment 2 discussed in Section 5.2.4).

(5.9) a. *N1-association neutral noun*
警察が今まさに少年に注目している。
Keisatu-ga ima masani syônen-ni cyûmokusiteiru.
police-NOM right now boy-to paying attention
'The police are paying attention to the boy right now.'

b. *N1-association neutral noun + GEN + N2-association possible noun*
警察が今まさに少年の性格に注目している。
Keisatu-ga ima masani syônen-no seikaku-ni cyûmokusiteiru.
police-NOM right now boy-GEN character-to paying attention
'The police are paying attention to the character of the boy right now.'

c. *N1-association typical noun*
警察が今まさに犯人に注目している。
Keisatu-ga ima masani hannin-ni cyûmokusiteiru.
police-NOM right now criminal-to paying attention
'The police are paying attention to the criminal right now.'

d. *N1-association typical noun + GEN + N2-association possible noun*
警察が今まさに犯人の性格に注目している。
Keisatu-ga ima masani hannin-no seikaku-ni cyûmokusiteiru.
police-NOM right now criminal-GEN character-to paying attention
'The police are paying attention to the character of the criminal right now.'

As in the first norming study, the RC information of the target items functions as the main clause information; the neutral and typical N1s are used as the direct objects (5.9a, c) or adjuncts to the N2 (5.9b, d). The mean scores for the *N1-association neutral* and *typical* conditions as in (5.9a) and (5.9c) were 3.1 and 3.7. This difference was statistically significant

($p < .05$), suggesting that the typical N1s were related to the RC information more strongly compared to the neutral N1s. The results also showed that the mean scores for the *N2-association possible* conditions as in (5.9b) and (5.9d) were 3.1 and 3.2, respectively; this difference was not significant. This suggests that the N2s in the *N2-association possible* conditions are plausible as RC head nouns, as intended. Furthermore, as already discussed, the results imply that it is not the case that the event typicality of the N2 association is higher when the N1 is typical for the N1 association analysis (5.9d) compared to when it is neutral (5.9b).

5.3.3. Results[25]

The results for the N1-GEN, N2-NOM, and main Predicate regions are reported in this section.[26] The means (with SEs) of the four measures in the three regions are presented in milliseconds for the reading times and in percentages for regressions-out in Table 5-3, and the statistical results from the best-fit LME models are shown in Table 5-4. The region-by-region results are reported. (Note again that we have to consider the results related to *N1-association Typicality*, particularly in interaction with *N2-association Possibility*, as not related to the parser's initial commitment to the N1 association analysis.)

[25] The results from all the participants are reported in this section because the whole group's mean accuracy for comprehension questions was 96.8% (SD = 5.5) and no participant's data were excluded from further analyses.

[26] See Appendix K for the results of the first three regions.

Table 5-3: The means (and SEs) of four eye-movement measures (Experiment 3)

Measures	N1-GEN *boy/criminal-GEN*	N2-NOM *character-NOM*	Main Predicate *TV gossip show-in taken up*
First-pass (with regressions)			
N2-association impossible + N1-association neutral	322 (18)	381 (22)	598 (72)
N2-association impossible + N1-association typical	383 (20)	339 (16)	613 (56)
N2-association possible + N1-association neutral	318 (14)	347 (24)	595 (74)
N2-association possible + N1-association typical	361 (28)	361 (16)	595 (61)
Regression-path			
N2-association impossible + N1-association neutral	380 (28)	477 (34)	2371 (246)
N2-association impossible + N1-association typical	477 (30)	499 (38)	2283 (253)
N2-association possible + N1-association neutral	396 (39)	594 (50)	2476 (261)
N2-association possible + N1-association typical	477 (45)	513 (46)	2790 (335)
Second-pass			
N2-association impossible + N1-association neutral	273 (44)	321 (35)	–
N2-association impossible + N1-association typical	354 (55)	286 (42)	–
N2-association possible + N1-association neutral	328 (40)	355 (44)	–
N2-association possible + N1-association typical	483 (68)	367 (56)	–
Regressions-out			
N2-association impossible + N1-association neutral	8 (3)	14 (3)	84 (5)
N2-association impossible + N1-association typical	12 (2)	17 (3)	80 (5)
N2-association possible + N1-association neutral	11 (4)	19 (3)	86 (4)
N2-association possible + N1-association typical	14 (4)	16 (4)	90 (4)

Note: A hyphen (–) indicates data irrelevant for the sentence-final region.

Table 5-4: The statistical results from the best-fit models for four eye-movement measures (Experiment 3)

Measures	N1-GEN				N2-NOM				Main Predicate			
	boy/criminal-GEN				*character-NOM*				*TV gossip show-in taken up*			
First-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	342.27	18.09			353.89	17.12			595.43	62.82		
N2Possibility	-11.52	14.30	-0.81		-4.15	13.00	-0.32		-13.40	40.24	-0.33	
N1Typicality	-49.69	19.59	-2.54	.015*	13.40	15.20	0.88		-3.26	38.55	-0.09	
Interaction	24.28	33.66	0.72		-52.40	25.98	-2.01	.04*	15.05	60.81	0.25	
Regression-path	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	429.42	27.94			519.48	25.51			2451.54	282.64		
N2Possibility	11.13	26.27	0.42		63.61	41.85	1.52		311.29	155.91	1.997	.051†
N1Typicality	-90.10	26.22	-3.44	.0006***	29.71	41.84	0.71		-94.89	164.43	-0.58	
Interaction	23.72	52.47	0.45		105.29	83.68	1.26		-435.90	262.75	-1.66	
Second-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	359.77	50.95			332.35	39.99			–	–	–	–
N2Possibility	92.20	35.03	2.63	.012*	57.09	26.57	2.15	.03*	–	–	–	–
N1Typicality	-117.89	44.63	-2.64	.011*	11.33	26.57	0.43		–	–	–	–
Interaction	-74.70	71.69	-1.04		-46.77	53.14	-0.88		–	–	–	–
Regressions-out	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
(Intercept)	-2.60	0.28			-1.74	0.16			2.59	0.40		
N2Possibility	0.17	0.14	1.21		0.08	0.11	0.76		0.34	0.14	2.50	.014*
N1Typicality	-0.22	0.14	-1.55		-0.01	0.11	-0.09		-0.00	0.13	-0.01	
Interaction	0.03	0.14	0.22		0.13	0.11	1.21		-0.26	0.14	-1.92	.06†

† p < .1, * p < .05, ** p < .01, *** p < .001

Note: N2Possibility stands for *N2-association Possibility* and N1Typicality for *N1-association Typicality*; a hyphen (–) indicates data irrelevant for the sentence-final region.

N1-GEN region (e.g., boy/criminal-*GEN)*

The results of first-pass and regression-path times in the N1-GEN region (Figures 5-7 and 5-8) showed a main effect of *N1-association Typicality*, indicating that this region was read more slowly in the *N1-association typical* conditions than in the *N1-association neutral* conditions.

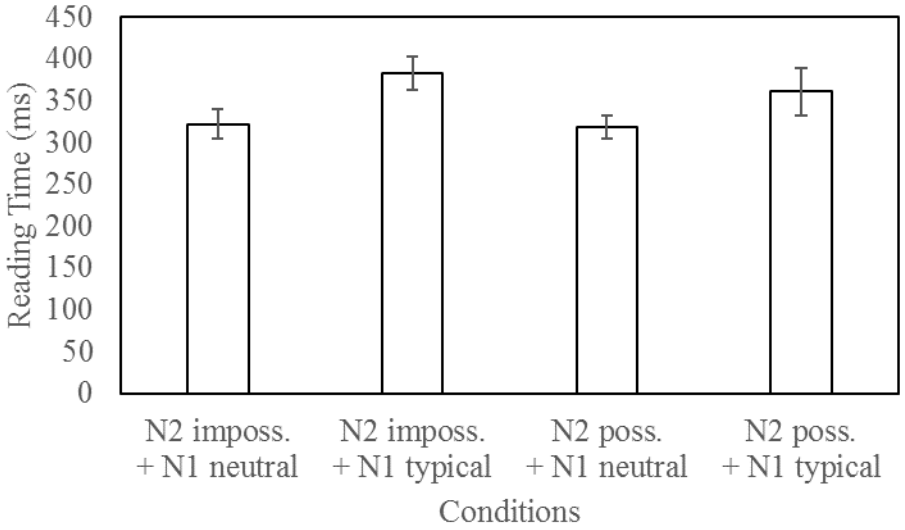


Figure 5-7: The mean first-pass times in the N1-GEN region (Experiment 3)

Note: The vertical axis stands for mean reading times in milliseconds (the error bars for SEs), and the horizontal axis for the four conditions (N2 imposs. + N1 neutral for *N2-association impossible* + *N1-association neutral*, N2 imposs. + N1 typical for *N2-association impossible* + *N1-association typical*, N2 poss. + N1 neutral for *N2-association possible* + *N1-association neutral*, and N2 poss. + N1 typical for *N2-association possible* + *N1-association typical*). The same holds in the following figures.

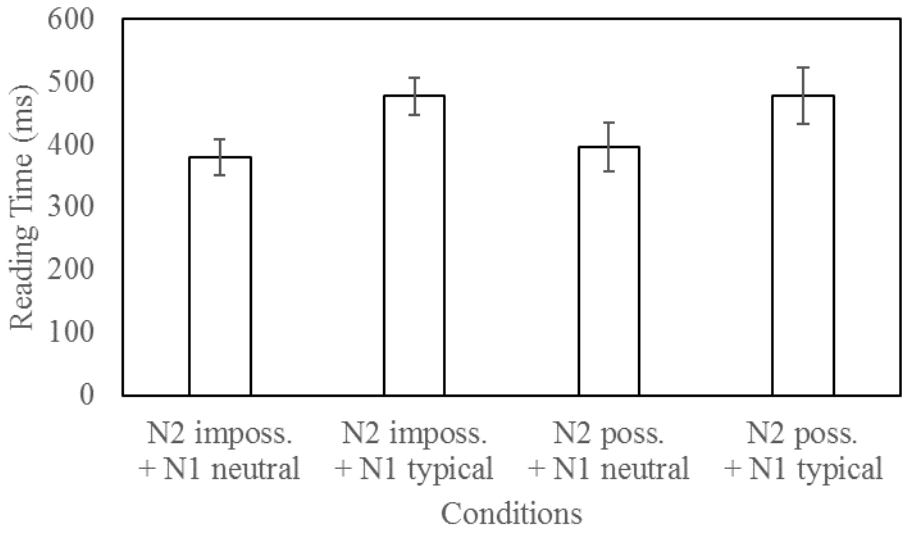


Figure 5-8: The mean regression-path times in the N1-GEN region (Experiment 3)

The results of second-pass times in the N1-GEN region (Figure 5-9) also showed a main effect of *N1-association Typicality*, suggesting that the participants spent longer in re-reading this region in the *N1-association typical* conditions compared to the *N1-association neutral* conditions.

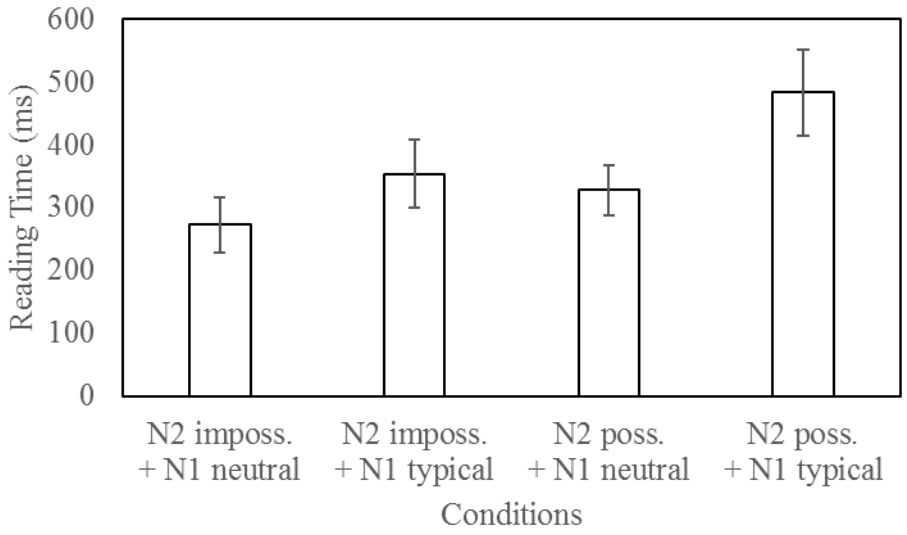


Figure 5-9: The mean second-pass times in the N1-GEN region (Experiment 3)

We did not predict these results, and we will discuss them considering the lexical difference in the types of noun used for the N1s in Section 5.3.4. The results presented in Figure 5-9 also

showed a main effect of *N2-association Possibility*, indicating that the participants took longer to re-read this region in the *N2-association possible* conditions compared to the *N2-association impossible* conditions. We will discuss this finding in terms of disambiguation costs in Section 5.3.4, as well.

N2-NOM region (e.g., character-*NOM)*

The results of first-pass times in the N2-NOM region (Figure 5-10) showed that an interaction between *N2-association Possibility* and *N1-association Typicality* was significant but main effects were not.

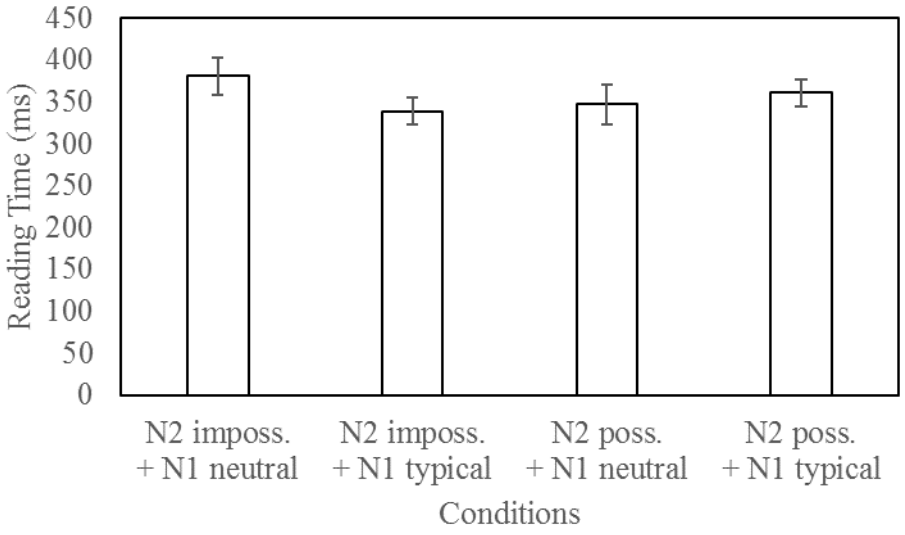


Figure 5-10: The mean first-pass times in the N2-NOM region (Experiment 3)

Further analyses indicated that a simple effect of *N1-association Typicality* was significant in the *N2-association impossible* conditions ($\beta = 19.62$, $SE = 9.08$, $t = 2.16$, $p < .05$). This finding suggests that when the N2 was impossible as the RC head noun, the participants took a shorter time to read this region in the *N1-association typical condition* compared to the *N1-association neutral* condition. The simple effect of *N1-association Typicality* was not

observed in the *N2-association possible* conditions.[27] As we predicted, a difference was found at the N2 between the *N2-association impossible* conditions. This result, however, is not attributable to the parser's initial commitment to the N1 association analysis, as we discuss in Section 5.3.4. The results of second-pass times in the N2-NOM region (Figure 5-11) showed a main effect of *N2-association Possibility*, indicating that the participants spent a longer time in re-reading this region in the *N2-association possible* conditions than in the *N2-association impossible* conditions.

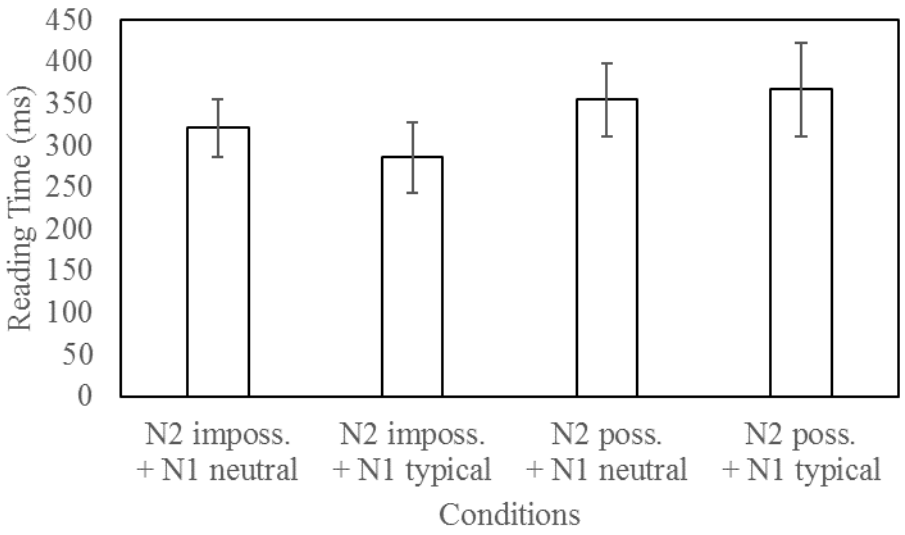


Figure 5-11: The mean second-pass times in the N2-NOM region (Experiment 3)

There was neither a main effect of *N1-association Typicality* nor an interaction of the two factors for second-pass times. Although we did not predict these results, the data pattern is the same as that found in the N1-GEN region, and therefore, in Section 5.3.4, we will discuss these results too in terms of disambiguation costs.

Main Predicate region (e.g., TV gossip show-in taken up*)*

The results of regression-path times in the main Predicate region (Figure 5-12) showed that the main effect of *N2-association Possibility* was almost significant, possibly indicating that

[27] The same pattern of interaction was found for first-pass times without regressions as well ($t > 2$).

the participants read this region more slowly in the *N2-association possible* conditions than in the *N2-association impossible* conditions.

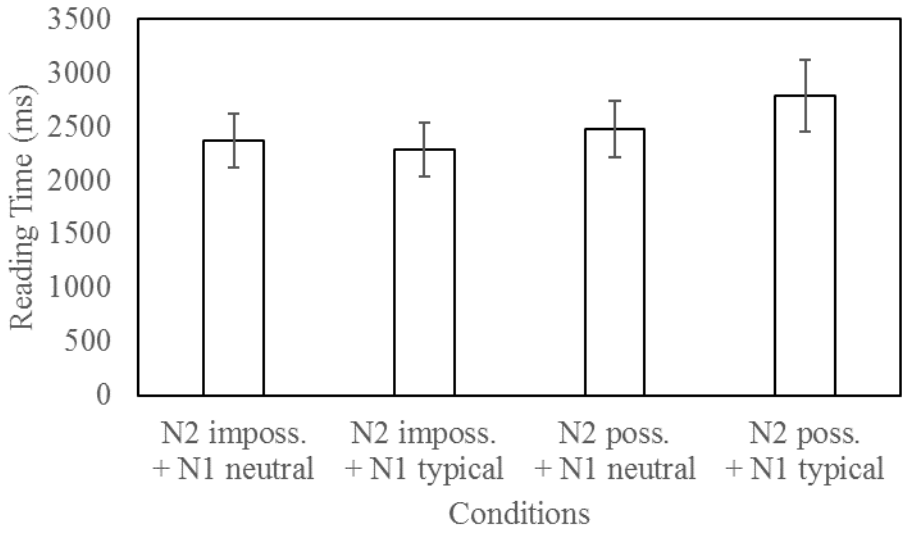


Figure 5-12: The mean regression-path times in the main Predicate region (Experiment 3)

The results of regressions-out in the main Predicate region (Figure 5-13) also showed a main effect of *N2-association Possibility*, indicating that the participants made regressive eye-movements more often in the *N2-association possible* conditions than in the *N2-association impossible* conditions.

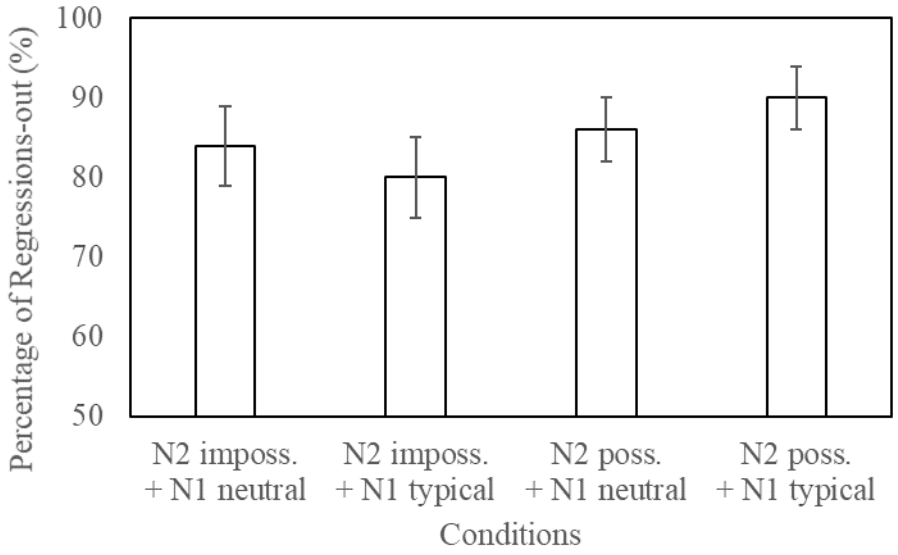


Figure 5-13: The mean ratios of regressions-out in the main Predicate region (Experiment 3)
Note: The vertical axis stands for the mean regressions-out in percentages (the error bars for SEs), and the horizontal axis for the four conditions.

We did not predict these results, but they suggest that the participants experienced greater difficulty when both N1 and N2 association analyses were possible compared to when only the N1 association analysis was possible. In Section 5.3.4, we will consider how the disambiguation process might be involved in these results. The results of regressions-out also showed an almost significant interaction of the two manipulations, although further analyses indicated that no simple effect of *N1-association Typicality* was found either in the *N2-association impossible* conditions or in the *N2-association possible* conditions (*p*s > .05).

5.3.4. Discussion

In Experiment 3, we examined whether the parser can consider the N2 association analysis prior to the N2 by expecting it at the genitive case marker attached to the N1. The experiment yielded two major findings. First, the results indicated no main effect of *N2-association Possibility* at the N2 in an early eye-movement measure, i.e., the participants did not show longer reading times at the N2 when it was impossible as the RC head noun compared to when it was possible, contrary to our first prediction. This finding suggests instead that it is

not always the case that the parser expects the N2 association analysis in advance at the genitive case marker attached to the N1.

Second, the results from first-pass reading times in the N2-NOM region showed a significant interaction between *N2-association Possibility* and *N1-association Typicality* (without main effects). Further analyses for the simple effect of *N1-association Typicality* revealed that when the N2 was semantically impossible to associate with the RC, the participants took longer to read the N2-NOM region in the *N1-association neutral* condition than in the *N1-association typical* condition. The simple effect of *N1-association Typicality* was not observed when the N2 association analysis was possible. A significant interaction of the two manipulations was found, as we predicted. Because we cannot assume that this effect of *N1-association Typicality* is related to the parser's initial commitment to the N1 association analysis, this difference in processing difficulty needs to be accounted for in another way. One possible reason is that the parser considers the N2 association analysis when the N1 is neutral, and thus experiences greater difficulty at the N2 when the N2 association analysis is impossible, compared to when the N1 is typical. If we assume that the parser does not consider the N2 association analysis when the N1 is typical, however, we cannot account for the results of Experiment 2, which suggest that the N2 association analysis is considered at the N2, irrespective of the rated typicality of the N1. An alternative account is that the nouns used for the neutral N1s (e.g., *syônen* 'boy') are very general in terms of meaning and thus comprehenders may not commit to the N1 association analysis at all but instead process the complex NP as a whole as the RC head. On the other hand, the nouns used for the typical N1s (e.g., *hannin* 'criminal') are semantically more specific and thus the comprehenders may commit to the N1 association analysis. If this is the case, comprehenders have to expect or consider the N2 association analysis in the *N1-association neutral* condition and thus will experience processing difficulty when the N2 association analysis turns out to be impossible due to the inanimate N2. This explanation may also account for the observed pattern of

interaction. Note, however, that this account cannot explain why, in Experiment 2, the N2 association analysis was considered at the N2 not only when the N1 was neutral but also when it was typical.

Furthermore, the results from second-pass reading times in the N1-GEN and N2-NOM regions showed a main effect of *N2-association Possibility*, revealing that the participants spent longer times re-reading these regions in the *N2-association possible* conditions than in the *N2-association impossible* conditions (the same pattern was observed for the second-pass reading times in the RC Adverb region; see Appendix K). The results from regression-path reading times in the main Predicate region showed that the main effect of *N2-association Possibility* was almost significant, indicating that the participants took longer to read this region in the *N2-association possible* conditions compared to the *N2-association impossible* conditions. The results from regressions-out in the main Predicate region also showed a main effect of *N2-association Possibility*, suggesting that the participants made regressive eye-movements more frequently in the *N2-association possible* conditions than in the *N2-association impossible* conditions. We did not predict these results, but they showed the same pattern, possibly implying that when the comprehenders can maintain the N2 association analysis, they might face the extra processing cost of disambiguation, as we discussed in regard to Experiment 2 (Section 5.2.4).

The results from first-pass and regression-path reading times in the N1-GEN region showed a main effect of *N1-association Typicality* (without a main effect of *N2-association Possibility* or an interaction between the two factors), indicating that the participants took longer to read this region in the *N1-association typical* conditions compared to the *N1-association neutral* conditions. The results from second-pass reading times in this region also showed a main effect of *N1-association Typicality*, suggesting that the participants spent a longer time in re-reading this region in the *N1-association typical* conditions than in the *N1-association neutral* conditions. The pattern of these reading times was the same as that

observed in Experiment 2, and thus it is attributable to the lexical difference in frequency (or specificity) because the nouns used for the N1s in the *N1-association typical* conditions are less frequent (or more specific) and thus may be harder to process compared to those in the *N1-association neutral* conditions, as discussed in regard to Experiment 2 (Section 5.2.4).

To summarize, the results of Experiment 3 suggest that the parser does not always consider the N2 association analysis in advance at the genitive case marker attached to the N1. Although the difference in the N1s might have affected the comprehenders' consideration of the N2 association analysis at the genitive case marker, we were not able to discover exactly what makes them expect, or not expect, the N2 association analysis.

5.4. General Discussion

Experiments 2 and 3 investigated the on-line processing of head association ambiguity in Japanese RCs using an eye-tracking reading method, to answer Research Question 2: Can the parser consider the N2 association analysis prior to the end of the sentence during real-time processing? The answer is yes. The results of Experiments 2 and 3 together suggest that the parser can consider the N2 association analysis as early as at the N2, although it does not necessarily consider it at the genitive case marker attached to the N1. Our concern is whether unforced (i.e., syntactically not required) revision from the N1 association analysis is involved in the parser's on-line consideration of the N2 association analysis. The results of Experiment 3 might support the possibility of such revision, because the results might imply that the parser retains its initial N1 association analysis when the N1 is typical for the analysis, but is more likely to perform revision when the N1 is neutral. The results of Experiment 2, however, suggest that comprehenders consider the N2 association analysis at the N2, irrespective of the rated typicality of the N1. Because our manipulation of *N1-association Typicality* was not effective (see Section 5.2.4), we cannot conclude that the parser's decision at the point of the N2 or at the point of the genitive case marker during on-line processing can be subject to

further revision downstream, or whether the N1's typicality as the RC head noun has an effect. While Experiments 2 and 3 provide evidence for the parser's on-line consideration of the N2 association analysis, they were not able to provide evidence for the parser's initial consideration of the N1 association analysis. To conclude that unforced revision is possible and takes place, we would have to demonstrate that the parser can indeed consider the N1 association analysis initially when both N1 and N2 association analyses are viable, which is the purpose of the on-line probe recognition experiments presented in Chapter 6.

5.5. Summary

The results of two eye-tracking reading experiments have suggested that the parser can consider the N2 association analysis at the N2 (or, possibly, even at the genitive case marker attached to the N1) in the real-time processing of head association ambiguity in Japanese RCs. Previous studies have provided clear evidence for the parser's initial commitment to the N1 association analysis at the N1, leaving a question as to whether unforced revision to the N2 association analysis ever takes place. We presented a novel finding demonstrating the parser's on-line consideration of the N2 association analysis, but the question of whether the parser indeed considers the N1 association analysis at the N1 initially, even when the N2 association analysis is viable, remains. This is the research question that we will answer in Chapter 6.

CHAPTER 6

ON-LINE PROBE RECOGNITION EXPERIMENTS

6.1. Introduction

Experiments 2 and 3 demonstrated that comprehenders consider the N2 association analysis at the N2 (or sometimes at the genitive case marker attached to the N1) in the real-time processing of relative clause (RC) head association ambiguity in Japanese. The remaining question (Research Question 3) is: Can the parser consider the N1 association analysis at the N1 initially when both N1 and N2 association analyses are available at the N2? We have to demonstrate that this is the case before we can conclude that unforced revision takes place. Therefore, two experiments were conducted to examine the parser's initial consideration of the N1 association analysis (Experiment 4) and the possibility of unforced revision (Experiment 5). These experiments adopt a post-sentential probe recognition technique (e.g., Bever & McElree, 1988; Nakayama, 1995). Participants first read a sentence; they then see a single word (i.e., the *probe*), and they judge whether it is a real word or a non-word. This probe recognition task incorporates a *priming* effect by which comprehenders can access the probe words quickly if the words are related to the overall meaning of the preceding sentence or to the constructed sentence structure. Hence, if comprehenders consider the N1 association analysis initially at the N1, they should respond to the words in the post-sentential probe recognition task more quickly when those words are related to the N1 association analysis compared to when they are not. If they do not commit to the N1 association analysis at any point, no difference in response times between related and non-related words should appear. These are the predictions to be examined in Experiment 4. Furthermore, if comprehenders consider the N2 association analysis at the N2, they should respond to probe words related to

the N2 association analysis more quickly than to probe words that are not. If they do not consider the N2 association analysis at any point, no difference should be observed between the two types of word. Experiment 5 investigated these predictions. Our participants read the same experimental sentences in both experiments, but they encountered different words as post-sentential probes in the two experiments. If unforced revision from the initial N1 association analysis is involved in comprehenders' consideration of the N2 association analysis, the predictions for both experiments should be borne out.

6.2. Experiment 4

6.2.1. Introduction

In Experiment 4, the words in the probe recognition task were manipulated as to whether they were "related" to the meaning conveyed by associating the N1 with the RC or not (i.e., "non-related"). We call this manipulation *N1-association Relatedness*. Related words, but not non-related words, were predicted to be primed by the N1 association interpretation (i.e., the meaning based on the syntactic structure of the N1 association analysis). Furthermore, sentence types in the reading task prior to the probe recognition task were manipulated: one type of sentence contained RCs with head association ambiguity while the other type of sentence contained different lexical items and no RCs. We call this manipulation *Sentence Type*. These two manipulations were fully crossed for a 2 (*experimental sentence* versus *baseline sentence*) x 2 (*word related to the N1 association* versus *word non-related to the N1 association*) design, as seen in the examples below (note that the terms *related* and *non-related* are relevant only to the *experimental* sentences).

(6.1) a. *Experimental sentence + Word related to the N1 association*
犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。
[Hannin-ga donki-de kôgekisita] dansei-no gaisya-ga
[RC criminal-NOM blunt instrument-with attacked] man-GEN foreign car-NOM
bôhan kamera-ni ututteita.
surveillance camera-by recorded
'The foreign car of the man that the criminal attacked with a blunt instrument was recorded by a surveillace camera.'
– 死亡
sibô
death
'death'

b. *Experimental sentence + Word non-related to the N1 association*
犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。
[Hannin-ga donki-de kôgekisita] dansei-no gaisya-ga
[RC criminal-NOM blunt instrument-with attacked] man-GEN foreign car-NOM
bôhan kamera-ni ututteita.
surveillance camera-by recorded
'The foreign car of the man that the criminal attacked with a blunt instrument was recorded by a surveillace camera.'
– 地球
tikyû
earth
'earth'

c. *Baseline sentence + Word related to the N1 association*
機内でスチュワーデスが乗客にビールをかけられた。
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta.
cabin-in flight attendant-NOM passenger-by beer-ACC splashed
'The flight attendant was splashed with beer by a passenger in the cabin.'
– 死亡
sibô
death
'death'

d. *Baseline sentence + Word non-related to the N1 association*
機内でスチュワーデスが乗客にビールをかけられた。
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta.
cabin-in flight attendant-NOM passenger-by beer-ACC splashed
'The flight attendant was splashed with beer by a passenger in the cabin.'
– 地球

tikyû
earth
'earth'

The sentences in (6.1a-b) contain a RC with head association ambiguity while the sentences in (6.1c-d) do not. We call the conditions in (6.1a-b) *experimental sentence* and the conditions in (6.1c-d) *baseline sentence*.[28] In (6.1a), the word *sibô* ('death') is related to the N1 association analysis because it can be the result of the event described by the N1 association interpretation (i.e., that a criminal attacked a man with a blunt instrument), whereas in (6.1b), the word *tikyû* ('earth') is not. Although neither word is ever related to the baseline sentences, we call the conditions in (6.1a, c) *word related to the N1 association* and the conditions in (6.1b, d) *word non-related to the N1 association*. The lexical frequency of the words used for the probe recognition task in the *word related to the N1 association* condition was almost the same as that of the words used in the *word non-related to the N1 association* condition, according to Amano and Kondo's (2000) corpus study (the mean occurrences were 6,770 for the "related" words and 6,992 for the "non-related" words out of the total token frequency of 287,792,797 words).

Given these four conditions, we make the following predictions. If participants consider the N1 association analysis at the N1 during on-line processing, their response time in the probe recognition task should be faster in the *experimental sentence + word related to the N1 association* condition, compared to the *experimental sentence + word non-related to the N1 association* condition. This is because the words in the former condition are primed by the N1 association interpretation and those in the latter condition are not. Moreover, no difference in response times should be found between the two baseline conditions. These patterns will

[28] For the probe recognition task, the experimental sentences and baseline sentences should consist of similar lexical items (this matter is discussed further in footnote 32). The baseline sentences were, however, composed of different words because they were the filler sentences used in Experiments 2 and 3. The reason for using the same non-target stimuli in all four experiments was to make the experimental environments as similar as possible.

result in an interaction of the two factors. Note that an interaction could be found even if comprehenders consider the N1 association analysis not at the N1 but at the sentence-final position. Although we cannot deny this possibility due to the post-sentential nature of the task, such a processing time course would be inconsistent with the incremental nature of processing. Therefore, this prediction is based on the assumption that the parser will consider the N1 association analysis at the N1 initially. If participants do not consider the N1 association analysis at all, no interaction should be observed.

6.2.2. Method

Participants

Sixteen students at the University of Tokyo and 28 students at Gunma University (i.e., 44 in total) were paid to participate in the experiment. They were all native Japanese speakers.

Materials

There were 12 experimental sentences and 12 baseline sentences, as in (6.1) (see Appendix L for the full set of items). The experimental sentences contained RC head association ambiguity, and the RC was consistently object-extracted as in (6.1a-b). The experimental and baseline sentences were counterbalanced in a Latin square design with two lists so that each participant saw the experimental sentence and the baseline sentence for each item in different conditions. For example, if one participant experienced the *word related to the N1 association* condition for the *experimental sentence* in one item, he/she also experienced the *word non-related to the N1 association* condition for the *baseline sentence* in the same item. Then, in a second item, he/she experienced the *word non-related to the N1 association* condition for the *experimental sentence* and the *word related to the N1 association* condition for the *baseline sentence*. There were also 48 fillers, which were of various syntactic types and never contained RCs. All 72 sentences were followed by

forced-choice comprehension questions. Both possible answers were correct for the 12 experimental sentences' comprehension questions, as the answers depended on the participant's RC head association preference. Hence, the remaining 60 questions were used to assess the participant's comprehension accuracy.

As for the probe recognition task, only real words were used for the 24 experimental and baseline sentences. For the 48 filler sentences, 12 real words and 36 non-words were used in the recognition task.[29] That is, the numbers of real words and of non-words were the same for the probe recognition task. All the words were two kanji characters in length, for example, 地球 (*tikyû* ('earth')) used as a real word and *亜臨 (non-meaningful combination of two kanji characters) used as a non-word (see Appendix L for all the real words and non-words used in the experiment). For each of the 24 experimental and baseline sentences, the number of morae of the related and non-related words was the same (for example, 死亡 (*sibô* ('death')) and 地球 (*tikyû* ('earth')) both have three morae).

Norming studies

Three norming studies were carried out for the experimental items. The first tested whether the N1s and N2s were plausible as the RC head nouns. Thirty native speakers of Japanese, who did not take part in the main experiment, were asked to evaluate the plausibility of 12 pairs of sentences as in (6.2) on a five-point scale from 1 for *very unlikely* to 5 for *very likely* (see Appendix M for the questionnaire used in this norming study).

[29] None of the non-words used in the experiment were listed in a Japanese dictionary (*Koujien*, 6th edition).

(6.2) a. *N1-association plausibility*
犯人が鈍器で男性を攻撃した。
Hannin-ga donki-de dansei-o kôgekisita.
criminal-NOM blunt instrument-with man-ACC attacked
'The criminal attacked the man with a blunt instrument.'

b. *N2-association plausibility*
犯人が鈍器で男性の外車を攻撃した。
Hannin-ga donki-de dansei-no gaisya-o kôgekisita.
criminal-NOM blunt instrument-with man-GEN foreign car-ACC attacked
'The criminal attacked the foreign car of the man with a blunt instrument.'

In (6.2a-b), the N1 and the sequence of the N1, genitive case marker, and N2 in the target items are used as the direct objects, and the subject and predicate are identical to the RC subject and predicate in the target items. This norming study's results showed no difference in head association plausibility between the N1 and the sequence of the N1, genitive case marker, and N2 (the mean scores were 4.6 for the former and 4.5 for the latter). These results suggest that both the N1 and the N2 can be considered plausible as the RC head nouns.

The second norming study was conducted to test whether, for the experimental sentences, the words in the *word related to the N1 association* condition were closely related to the N1 association interpretation while the words in the *word non-related to the N1 association* condition were not, and that both types of word were never related to the baseline sentences.[30] Eighteen native Japanese speakers, who did not take part in the main experiment, were asked to evaluate the ease of imagining the target words after reading sentences as in (6.3a-d) on a five-point scale from 1 for *very hard to imagine* to 5 for *very easy to imagine* (the terms *related* and *non-related words* are relevant only to the *N1 association interpretation sentences* in (6.3a-b); see Appendix N for the questionnaire used in this norming study).

[30] The words in the *word related to the N1 association* condition were chosen based on the results of another questionnaire study. Thirty-four native Japanese speakers were asked to write as many words as possible that could refer to an outcome of the events described by the N1 association interpretations. For each item, the most frequent word was chosen from the words that could not also be related to the N2 association interpretation. The words in the *word non-related to the N1 association* condition were chosen by considering length (number of morae) and lexical frequency based on Amano and Kondo's (2000) corpus study.

(6.3) a. *N1 association interpretation sentence + Word related to the N1 association*
犯人が鈍器で男性を攻撃した。―「死亡」
Hannin-ga donki-de dansei-o kôgekisita. – sibô
criminal-NOM blunt instrument-with man-ACC attacked death
'The criminal attacked the man with a blunt instrument.' 'death'

b. *N1 association interpretation sentence + Word non-related to the N1 association*
犯人が鈍器で男性を攻撃した。―「地球」
Hannin-ga donki-de dansei-o kôgekisita. – tikyû
criminal-NOM blunt instrument-with man-ACC attacked earth
'The criminal attacked the man with a blunt instrument.' 'earth'

c. *Baseline sentence + Word related to the N1 association*
機内でスチュワーデスが乗客にビールをかけられた。―「死亡」
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta. – sibô
cabin-in flight attendant-NOM passenger-by beer-ACC splashed death
'The flight attendant was splashed with beer by a passenger in the cabin.' 'death'

d. *Baseline sentence + Word non-related to the N1 association*
機内でスチュワーデスが乗客にビールをかけられた。―「地球」
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta. – tikyû
cabin-in flight attendant-NOM passenger-by beer-ACC splashed earth
'The flight attendant was splashed with beer by a passenger in the cabin.' 'earth'

The results indicated that the words in the *word related to the N1 association* condition were more closely related to the N1 association interpretation sentences compared to the words in the *word non-related to the N1 association* condition (the mean scores were 3.7 for the related words and 1.4 for the non-related words). No difference was found between the two types of word in the baseline sentences (the mean scores were 1.4 for both types of word). These results suggest that only the words in the *N1 association interpretation sentence + word related to the N1 association* condition, as in (6.3a), were relatively easy to imagine, as intended. Note, however, that although the ease of imagining the words in this condition is related to the interpretation of the preceding sentence, we cannot deny the possibility of a semantic priming effect from the lexical items. For example, each of the words *hannin* ('criminal'), *donki* ('blunt instrument'), and *kôgeki* ('attack') may be related to the meaning of *sibo* ('death'). If this is the case, semantic priming alone could account for the results of the

probe recognition task, regardless of the RC head association (although such semantic priming account is possible for only some of the stimuli; see Appendix L). We will consider this issue in more detail when we discuss the experimental results in Section 6.2.4.

Finally, the third norming study was conducted to test whether the words used in the *word related to the N1 association* condition were ever related to the N2 association interpretation (i.e., the meaning constructed by associating the N2 with the RC). Eighteen Japanese speakers, who did not participate in the main experiment, evaluated the ease of imagining the words after reading sentences as in (6.4), on the same five-point scale (see Appendix N for the questionnaire, which is the same that used in the second norming study).

(6.4) *N2 association interpretation sentence + Word related to the N1 association*
犯人が鈍器で男性の外車を攻撃した。―「死亡」
Hannin-ga donki-de dansei-no gaisya-o kôgekisita. – sibô
criminal-NOM blunt instrument-with man-GEN foreign car-ACC attacked death
'The criminal attacked the foreign car of the man with a blunt instrument.' 'death'

The mean score was 2.9, suggesting that it is less likely that the words in the *word related to the N1 association* condition are related to the N2 association interpretation, compared to the N1 association interpretation. In fact, the results of the second norming study above showed that the words in the *word related to the N1 association* condition were more closely related to the N1 association interpretation (the mean score was 3.7).

Procedure

The experiment was presented to each participant individually on a PC running Linger software. The participant completed a series of three tasks for each item before moving onto the next item. The items were presented in a random order, which was controlled by Linger. The first task was self-paced reading in a moving-window, noncumulative fashion (Just, Carpenter, & Woolley, 1982; Just & Carpenter, 1992), where a sentence appears on screen in

segments, and the participant controls the speed with which each segment appears and disappears. A series of dashes appears on the PC screen; when the participant presses the space key, a single dash is replaced with a word or phrase. When the participant again presses the space key, that word or phrase disappears, and another dash is replaced with a word or phrase. In this task, the participant read sentences as in (6.5a-b). (The slashes show the segmentation for the self-paced reading task.)

(6.5) a. *Experimental sentence*
犯人が鈍器で攻撃した男性の外車が / 防犯カメラに / 映っていた。
[Hannin-ga donki-de kôgekisita] dansei-no gaisya-ga /
[RC criminal-NOM blunt instrument-with attacked] man-GEN foreign car-NOM
bôhan kamera-ni / ututteita.
surveillance camera-by recorded
'The foreign car of the man that the criminal attacked with a blunt instrument was recorded by a surveillane camera.'

b. *Baseline sentence*
機内でスチュワーデスが / 乗客に / ビールをかけられた。
Kinai-de sucyuwâdesu-ga / jyôkyaku-ni / bîru-o kakerareta.
cabi-in flight attendant-NOM passenger-by beer-ACC splashed
'The flight attendant was splashed with beer by a passenger in the cabin.'

All the sentences were segmented into three regions as seen in (6.5a-b). For each item, after pressing the space key for the final word or phrase, the participant started the second task. In this probe recognition task, two kanji characters appeared in the center of the PC screen; for example, the two-character word in (6.6) might appear after one of the sentences in (6.5a).

(6.6) 死亡
sibô
death
'death'

The participant judged whether the two kanji characters were a real word or a non-word by pressing keys labeled “yes” and “no.” His/her response time was measured in milliseconds. The third task then began, as a forced-choice comprehension check appeared on the screen. For example, the participant might see the question in (6.7) asking about the sentence in (6.5a).

(6.7) 犯人が鈍器で攻撃したのは？　　男性　　外車

Hannin-ga	donki-de	kôgekisita	no-wa?	dansei	gaisya
criminal-NOM	blunt instrument-with	attacked	thing/person-TOP	man	foreign car

‘What/Who did the criminal attack with a blunt instrument? man foreign car’

The participant pressed the left or the right key to select an answer. The left/right position of the two possible answers was counterbalanced.

After eight practice trials, the participant started the main session with 72 trials. The participant received no feedback. The tasks have no time limit. Most participants took approximately twenty minutes to finish the experimental session.

Data treatment

First, the participants’ comprehension accuracy was calculated by their responses to the questions accompanying the 12 baseline sentences and 48 filler sentences.

Second, the participants’ response times in the probe recognition task were analyzed. The trails with incorrect responses either in the probe recognition task or in the comprehension check task were first excluded (overall, 12.3% of the data were eliminated in this step). Next, response times below 300 milliseconds and above 2,500 milliseconds were eliminated as outliers (2.5% of the data were thus eliminated). Finally, response times beyond 2.5 SDs above or below each participant’s mean were replaced with the boundary values (approximately 3.2% of the data were affected by this process). The remaining response time data were analyzed by Linear Mixed-Effects (LME) models. For the LME modeling, *Sentence*

Type (*experimental sentence* or *baseline sentence*) and *N1-association Relatedness* (*word related to the N1 association* or *word non-related to the N1 association*) were entered as two fixed effects, which were centered (i.e., effect coding), and participants and items were entered as two random effects. The best-fit model was chosen by a backward selection approach from the maximal structure consisting of a random intercept and slope of each fixed effect for both participants and items. The estimated coefficients (β), standard errors (*SE*), and *t* and *p* values are reported in Section 6.2.3.

Third, the participants' mean ratios of N2 association interpretation choices were calculated and compared between the *word related to the N1 association* and *word non-related to the N1 association* conditions. They were analyzed using generalized LME modeling in which *N1-association Relatedness* (*word related to the N1 association* or *word non-related to the N1 association*) was entered as one centered fixed effect, and participants and items were entered as two random effects. The best-fit model was chosen by a backward selection approach. The estimated coefficients (β), standard errors (*SE*), and *z* and *p* values are reported in Section 6.2.3.

6.2.3. Results[31]

First, the participants' mean accuracy was 91.6% (SD = 4.5).

Second, the results of their mean response times in the probe recognition task are shown in Figure 6-1.

[31] One participant's data were excluded from further analyses due to low accuracy in the probe recognition task (50%).

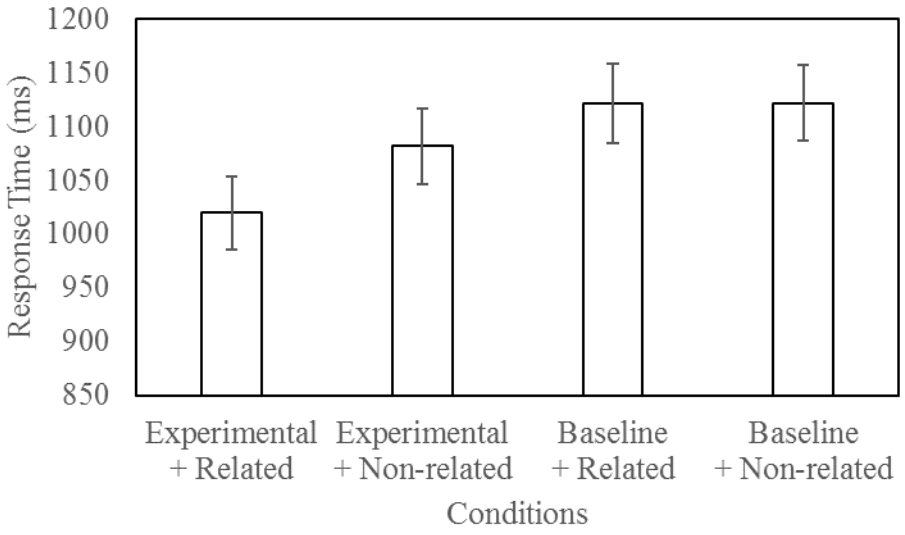


Figure 6-1: The mean response times in the probe recognition task (Experiment 4)

Note: The vertical axis stands for mean response times in milliseconds (the error bars for SEs), and the horizontal axis for the four conditions (Experimental + Related for *experimental sentence + word related to the N1 association*, Experimental + Non-related for *experimental sentence + word non-related to the N1 association*, Baseline + Related for *baseline sentence + word related to the N1 association*, and Baseline + Non-related for *baseline sentence + word non-related to the N1 association*).

The mean response times were 1020 milliseconds (SE = 34) in the *experimental sentence + word related to the N1 association* condition, 1082 milliseconds (SE = 35) in the *experimental sentence + word non-related to the N1 association* condition, 1122 milliseconds (SE = 37) in the *baseline sentence + word related to the N1 association* condition, and 1122 milliseconds (SE = 35) in the *baseline sentence + word non-related to the N1 association* condition. The best-fit model showed that there was a significant interaction between *Sentence Type* and *N1-association Relatedness* (β = -69.55, *SE* = 29.02, t = -2.40, $p < .05$). Further analyses indicated that a simple effect of *N1-association Relatedness* was not significant but was nearly so in the *experimental sentence* conditions (β = 43.50, *SE* = 30.01, t = 1.45, p = .15). This finding suggests that when the experimental sentences with RC head association ambiguity preceded the probe recognition task, the participants responded to the words related to the N1 association interpretation faster compared to the non-related words. The simple effect of *N1-association Relatedness* was not significant in the *baseline sentence* conditions (*p*

= 1.0). As predicted, a significant interaction was found, implying that the participants responded fastest to the words related to the N1 association interpretation. There was also a main effect of *Sentence Type* (β = 82.08, *SE* = 23.73, t = 3.46, $p < .01$), indicating that the participants responded to the words, whether related or non-related, faster in the *experimental sentence* conditions than in the *baseline sentence* conditions. We did not predict this result, which we will consider in terms of the difference between these conditions in Section 6.2.4. No main effect of *N1-association Relatedness* was observed (t = 0.89).

Third, the participants' mean ratios of the choice of the N2 association interpretation are shown in Figure 6-2.

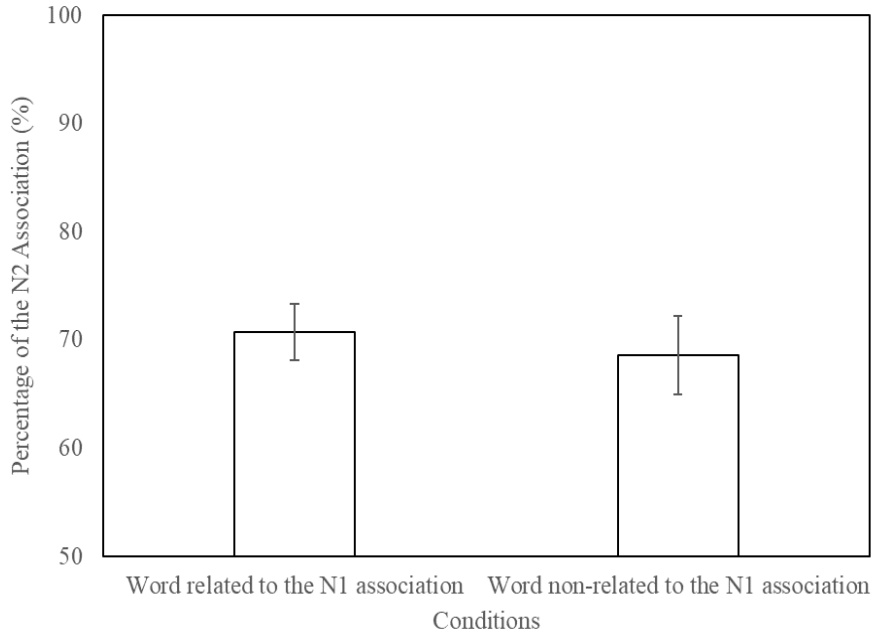


Figure 6-2: The mean ratios of the N2 association in the two conditions (Experiment 4)
Note: The vertical axis stands for the mean ratio of the N2 association in percentages (error bars for SEs) and the horizontal axis for the two conditions.

The mean ratios of the N2 association were 70.7% (SE = 2.6) in the *word related to the N1 association* condition and 68.6% (SE = 3.6) in the *word non-related to the N1 association* condition. The best-fit LME model indicated that there was no significant difference between them (p = .69).

6.2.4. Discussion

In Experiment 4, we examined whether comprehenders can consider the N1 association analysis initially during on-line processing. The results of the response times in the probe recognition task showed a significant interaction between *Sentence Type* and *N1-association Relatedness*. Further analyses indicated that after reading the *experimental* sentences with head association ambiguity, the participants responded to the probe words in the *word related to the N1 association* condition faster compared to those in the *word non-related to the N1 association* condition. For the *baseline* sentences without RCs, on the other hand, no difference in the response times was found between the "related" and "non-related" words. This pattern of interaction is consistent with our prediction, suggesting that the participants considered the N1 association analysis at the N1 (i.e., prior to the recognition task), because if the N1 association interpretation were *not* already established, they would not respond faster to the words that are considered to be related to the N1 association interpretation. An alternative account is that only lexical semantic priming is involved in the difference in response times between the *experimental sentence + word related to the N1 association* and *experimental sentence + word non-related to the N1 association* conditions. That is, the comprehenders may expect the words in the probe recognition task in the former condition after encountering specific words in the preceding sentence (i.e., primes), and therefore be able to respond quickly to the probe words even without considering the N1 association analysis. We cannot deny that such semantic priming is a possibility based only on the results of Experiment 4, but we will reconsider this account in light of the results of Experiment 5, which follows (Section 6.3).[32]

[32] If the baseline sentences contained lexical items identical or similar to those used in the experimental sentences, but did not contain RCs (see footnote 28), the semantic priming account would predict faster response times to the "related" words, which are primed only when the N1 association interpretation is established, even in the *baseline sentence* condition. Examining this prediction would be one way to assess the semantic priming account. This issue is left for a future study.

A question remains as to why the observed response times were relatively long. In earlier studies employing the lexical decision tasks, native Japanese speakers' mean response times for real words composed of two kanji characters have been approximately 700 to 800 milliseconds (e.g., Tamaoka, 2007). Experiment 4's longer response times raise the question of whether factors other than lexical decisions had an effect. One possibility is that the participants had difficulty deciding that the non-meaningful combinations of two kanji characters were non-words, which might have led them to be particularly careful about their lexical decisions even for real words, resulting in the increased response times.[33] Because the mean response times were more than 1000 milliseconds in the *baseline sentence* conditions as well, it is not the case that this question is specific to the *experimental sentence* conditions.

The results of the comprehension check task for the *experimental* sentences with RC head association ambiguity showed that the participants chose the N2 association interpretation more frequently compared to the N1 association interpretation. This N2 association preference was found in both *word related to the N1 association* and *word non-related to the N1 association* conditions. No main effect of *N1-association Relatedness* was observed, implying that when the words related to the N1 association interpretation were presented prior to the comprehension questions, they did not lead to a preference for the N1 association interpretation. Instead, the results from the comprehension check questions showed the participants' N2 association preference.

These results together suggest that during their on-line processing in the reading task, the participants considered the N1 association analysis at the N1 initially, that is, prior to the probe recognition task, which resulted in the priming effect. Then, after that initial consideration of the N1 association analysis, they reinterpreted the RC head noun as associated with the N2, which led them to prefer the N2 association interpretation in the comprehension check task after the probe recognition task. If Experiment 4's results reflect

[33] In fact, some of the participants told the experimenter that they had difficulty deciding whether the meaningless two-character combinations were non-words or simply words that they did not know.

unforced revision, comprehenders should respond faster to words related to the N2 association interpretation when they associate the N2 with the RC during on-line processing prior to a probe recognition task. Examining whether they do so is the purpose of Experiment 5.

The results of the response times in the recognition task also showed a main effect of *Sentence Type*, indicating shorter response times to the probe words in the *experimental sentence* conditions compared to those in the *baseline sentence* conditions. One possible interpretation is that neither the "related" nor the "non-related" words were related to the *baseline* sentences, whereas the "related" words, but not the "non-related" words, were closely related to the *experimental* sentences. If this is the case, only the "related" words in the *experimental sentence* conditions would have provided a response-time advantage, which could have resulted in the main effect of *Sentence Type*.

6.3. Experiment 5

6.3.1. Introduction

In Experiment 5, the words in the probe recognition task were manipulated as to whether they were "related" or "non-related" to the meaning constructed by the syntactic structure of the N2 association analysis. We call this *N2-association Relatedness*. In addition, we manipulated *Sentence Type* as in Experiment 4. These two manipulations were fully crossed to create a 2 (*experimental sentence* versus *baseline sentence*) x 2 (*word related to the N2 association* versus *word non-related to the N2 association*) design, resulting in the examples below (note again that the terms *related* and *non-related* are relevant only to the *experimental* sentences).

(6.8) a. *Experimental sentence + Word related to the N2 association*
犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。
[Hannin-ga donki-de kougekisita] dansei-no gaisya-ga
[RC criminal-NOM blunt instrument-with attacked] man-GEN foreign car-NOM
bôhan kamera-ni ututteita.
surveillance camera-by recorded
'The foreign car of the man that the criminal attacked with a blunt instrument was recorded by a surveillane camera.'
– 破壊
hakai
destruction
'destruction'

b. *Experimental sentence + Word non-related to the N2 association*
犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。
[Hannin-ga donki-de kougekisita] dansei-no gaisya-ga
[RC criminal-NOM blunt instrument-with attacked] man-GEN foreign car-NOM
bôhan kamera-ni ututteita.
surveillance camera-by recorded
'The foreign car of the man that the criminal attacked with a blunt instrument was recorded by a surveillane camera.'
– 当初
tôsyo
beginning
'beginning'

c. *Baseline sentence + Word related to the N2 association*
機内でスチュワーデスが乗客にビールをかけられた。
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta.
cabin-in flight attendant-NOM passenger-by beer-ACC splashed
'The flight attendant was splashed with beer by a passenger in the cabin.'
– 破壊
hakai
destruction
'destruction'

d. *Baseline sentence + Word non-related to the N2 association*
機内でスチュワーデスが乗客にビールをかけられた。
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta.
cabin-in flight attendant-NOM passenger-by beer-ACC splashed
'The flight attendant was splashed with beer by a passenger in the cabin.'
– 当初

tôsyo
beginning
'beginning'

The *experimental sentence* in (6.8a-b) contains head association ambiguity while the *baseline sentence* in (6.8c-d) does not. The word *hakai* 'destruction' in (6.8a) is closely related to the N2 association interpretation because destruction could be the consequence of the interpretation that, with a blunt instrument, the criminal attacked the man's foreign car. On the other hand, the word *tôsyo* ('beginning') in (6.8b) is not related to the N2 association interpretation. Although neither of these words are related to the baseline sentences, we call the conditions in (6.8a, c) *word related to the N2 association* and the conditions in (6.8b, d) *word non-related to the N2 association*. As in Experiment 4, the lexical frequency of the "related" words was almost the same as that of the "non-related" words according to Amano and Kondo's (2000) frequency counts (mean occurrences of the former and latter words were 5,881 and 6,098, respectively, out of 287,792,797 words for the total token frequency).

Given the four conditions exemplified in (6.8a-d), our predictions are as follows. If comprehenders consider the N2 association analysis at the N2 as a result of revision from their initial N1 association analysis, they should respond faster to the probe words in the *experimental sentence + word related to the N2 association* condition as in (6.8a) compared to the probe words in the *experimental sentence + word non-related to the N2 association* condition as in (6.8b). In addition, no difference should be found in response times to the "related" and "non-related" words in the *baseline sentence* conditions as in (6.8c-d). Such a pattern of responses would lead to an interaction of the two manipulations. If comprehenders do not consider the N2 association analysis at all, no such interaction will be observed. Note that the alternative account based on lexical semantic priming, which we discussed in regard to Experiment 4 (Section 6.2.4), instead predicts a significant interaction in such a case. That is, if the "related" words are semantically primed by specific lexical items in the preceding

sentence, then comprehenders should respond quickly to the "related" words in the *experimental sentence* condition even if they do not consider the N2 association analysis.

6.3.2. Method

Participants

Fourteen undergraduates at the University of Tokyo and 34 undergraduates at Gunma University (i.e., 48 in total) were paid to take part in Experiment 5. They were all native speakers of Japanese.

Materials, procedure, and data treatment

The same materials, procedure, and data treatment as in Experiment 4 were used. As for the data treatment, first, the trials with incorrect responses were excluded (overall, 7.7% of the data were excluded through this process). Second, response times below 300 milliseconds and above 2,600 milliseconds were eliminated as outliers in the probe recognition task (0.7% of the data were thus excluded). Third, response times beyond 2.5 SDs above or below each participant's mean were replaced with the boundary values (approximately 2.7% of the data were affected by this trimming).

Norming Studies

Due to the new manipulation of *N2-association Relatedness*, the "related" and "non-related" words in *experimental sentence* and *baseline sentence* conditions were changed (see Appendix O for all the words used in the probe recognition task in Experiment 5). Because of this change, two norming studies were carried out. One was designed to test whether the words in the *word related to the N2 association* condition are indeed closely related to the N2 association interpretation while the words in the *word non-related to the N2 association* condition are not, and to verify that these two types of word are never related to

the baseline sentences at all.[34] The participants were 18 native Japanese speakers who did not participate in the main experiment. They were asked to assess the ease of imagining the "related" and "non-related" words after reading sentences, as in (6.9), on a five-point scale from 1 for *very hard to imagine* to 5 for *very easy to imagine* (see Appendix N for the questionnaire, which was also used in the second and third norming studies of Experiment 4).

(6.9) a. *N2 association interpretation sentence + Word related to the N2 association*
犯人が鈍器で男性の外車を攻撃した。―「破壊」
Hannin-ga donki-de dansei-no gaisya-o kôgekisita.
criminal-NOM blunt instrument-with man-GEN foreign car-ACC attacked
'The criminal attacked the foreign car of the man with a blunt instrument.'
– hakai
destruction
'destruction'

b. *N2 association interpretation sentence + Word non-related to the N2 association*
犯人が鈍器で男性の外車を攻撃した。―「当初」
Hannin-ga donki-de dansei-no gaisya-o kôgekisita.
criminal-NOM blunt instrument-with man-GEN foreign car-ACC attacked
'The criminal attacked the foreign car of the man with a blunt instrument.'
– tôsyo
beginning
'beginning'

c. *Baseline sentence + Word related to the N2 association*
機内でスチュワーデスが乗客にビールをかけられた。―「破壊」
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta. – hakai
cabin-in flight attendant-NOM passenger-by beer-ACC splashed destruction
'The flight attendant was splashed with beer by a passenger in the cabin.' 'destruction'

d. *Baseline sentence + Word non-related to the N2 association*
機内でスチュワーデスが乗客にビールをかけられた。―「当初」
Kinai-de sucyuwâdesu-ga jyôkyaku-ni bîru-o kakerareta. – tôsyo
cabin-in flight attendant-NOM passenger-by beer-ACC splashed beginning
'The flight attendant was splashed with beer by a passenger in the cabin.' 'beginning'

[34] The words were chosen in the same way as they were chosen for Experiment 4 (see footnote 30).

The results showed that for the *experimental* sentences, the words in the *word related to the N2 association* condition were related to the N2 association interpretation more closely compared to the words in the *word non-related to the N2 association* condition (the mean scores were 3.9 for the former and 1.5 for the latter). The results also indicated no difference between the "related" and "non-related" words for the *baseline* sentences (the mean scores were 1.4 for the former and 1.6 for the latter).

The other norming study was conducted to verify that the words related to the N2 association interpretation are never related to the N1 association interpretation. The respondents were 18 native speakers of Japanese, who did not take part in the main experiment. They evaluated the ease of imagining the target words after reading sentences, as in (6.10), on the same five-point scale (1 for *very hard to imagine* to 5 for *very easy to imagine*; again, see Appendix N for the questionnaire).

(6.10) *N1 association interpretation sentence + Word related to the N2 association*
犯人が鈍器で男性を攻撃した。―「破壊」
Hannin-ga donki-de dansei-o kôgekisita. – hakai
criminal-NOM blunt instrument-with man- ACC attacked destruction
'The criminal attacked the man with a blunt instrument.' 'destruction'

The results indicated that the mean score was 2.6, suggesting that the words related to the N2 association are less likely to be related to the N1 association interpretation compared to the N2 association interpretation, as intended. Note that the results of the above first norming study showed that the words related to the N2 association were more closely related to the N2 association interpretation (the mean score was 3.9).

6.3.3. Results[35]

First, the participants' mean accuracy was 89.2% (SD = 5.7).

[35] One participant's data were excluded due to low accuracy in the probe recognition task (48.6%).

Second, Figure 6-3 shows the results of the participants' mean response times in the probe recognition task.

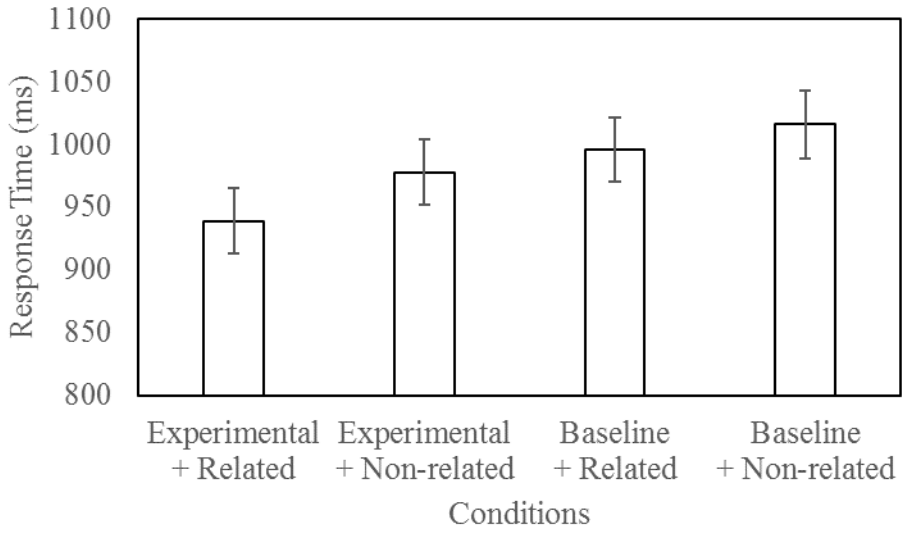


Figure 6-3: The mean response times in the probe recognition task (Experiment 5)

Note: The vertical axis stands for mean response times in milliseconds (the error bars for SEs), and the horizontal axis for the four conditions (Experimental + Related for *experimental sentence + word related to the N2 association*, Experimental + Non-related for *experimental sentence + word non-related to the N2 association*, Baseline + Related for *baseline sentence + word related to the N2 association*, and Baseline + Non-related for *baseline sentence + word non-related to the N2 association*).

The mean response times in the four conditions were as follows: 939 milliseconds (SE = 26) in the *experimental sentence + word related to the N2 association* condition, 978 milliseconds (SE = 26) in the *experimental sentence + word non-related to the N2 association* condition, 996 milliseconds (SE = 26) in the *baseline sentence + word related to the N2 association* condition, and 1016 milliseconds (SE = 27) in the *baseline sentence + word non-related to the N2 association* condition. The best-fit model, chosen through backward selection, showed a marginal main effect of *Sentence Type* ($\beta = 44.33$, $SE = 25.92$, $t = 1.71$, $p = .095$), indicating that the participants responded faster to the probe words in the *experimental sentence* conditions than in the *baseline sentence* conditions, regardless of the difference between related and non-related words. Although we did not predict these results, the same pattern was

observed in Experiment 4, as we will discuss further in Section 6.3.4. There was no main effect of *N2-association Relatedness* (t = 1.16). Contrary to our prediction, we found no significant interaction of the two factors (t = -0.63). We will discuss this finding in Section 6.3.4 as well, also considering it in light of the results of Experiment 4.

Third, the results of the participants' mean ratios of choosing the N2 association interpretation in the comprehension check task are presented in Figure 6-4.

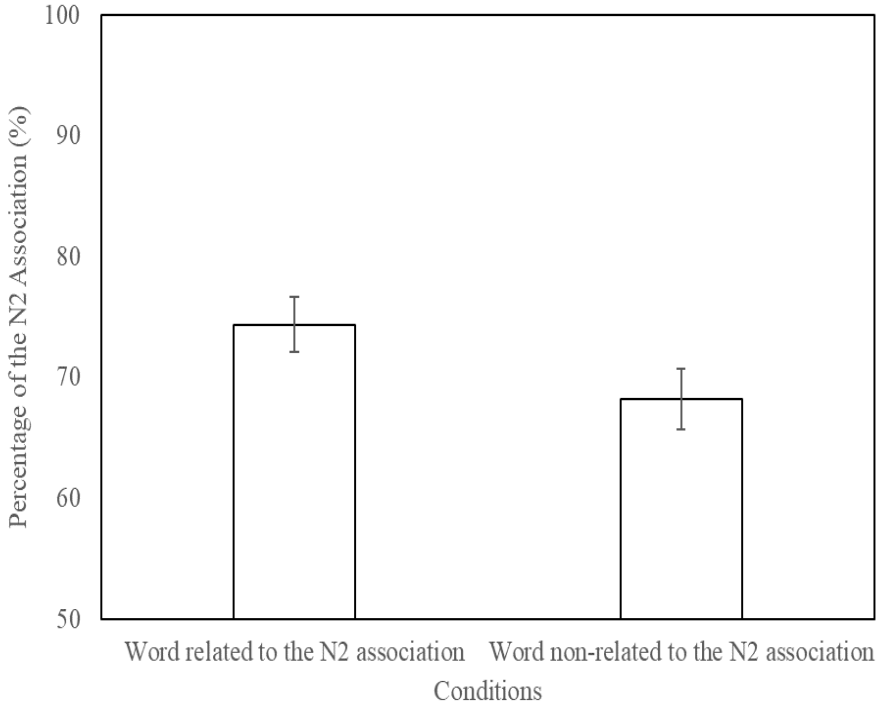


Figure 6-4: The mean ratios of the N2 association in the two conditions (Experiment 5)
Note: The vertical axis stands for the mean ratio of the N2 association in percentages (error bars for SEs) and the horizontal axis for the two conditions.

The mean ratios of the N2 association were 74.4% (SE = 2.3) in the *word related to the N2 association* condition and 68.2% (SE = 2.5) in the *word non-related to the N2 association* condition. The best-fit model indicated that this difference was significant (β = -0.44, SE = 0.21, t = -2.10, $p < .05$). This suggests that the participants chose the N2 association interpretation more frequently in the former condition than in the latter condition.

6.3.4. Discussion

The results of the response times in the probe recognition task did not show an interaction between *Sentence Type* and *N2-association Relatedness*, contrary to our prediction. We suggest that the lexical semantic priming effect that we discussed in regard to Experiment 4 cannot account for these results because it predicts a significant interaction. The results are also inconsistent with our assumption that comprehenders consider the N2 association analysis at the N2, which also would have led to a significant interaction. Our concern is why we did not observe a significant interaction of the two manipulations as a result of the priming effect. The results of the comprehension check task showed an overall bias towards the N2 association interpretation. Moreover, the results indicated a main effect of *N2-association Relatedness*, suggesting that the participants chose the N2 association interpretation more often in the *word related to the N2 association* condition than in the *word non-related to the N2 association* condition. This finding possibly implies that because the words in the former condition were related to the N2 association interpretation, the participants were more likely to choose that interpretation. It might be the case that the N2 association interpretation was established by the time of comprehension check task but not yet by the time of the preceding probe recognition task. If so, a possible explanation could be that the N2 association interpretation is the result of the comprehenders' consideration of the coherence of the whole sentence, as suggested in our discussion of Experiment 1 (Chapter 4), and thus may take a longer time to be established than the N1 association interpretation. This explanation is apparently contradictory to the results of Experiment 2, which suggested that the parser had difficulty when the meaning conveyed by the N2 association analysis was incompatible with the sentence-final main predicate (Chapter 5). We, however, do not suggest that the parser never establishes the N2 association interpretation by the end of the sentence, but rather that the N2 association interpretation may not have been completed in time to produce a robust effect at the time of the probe recognition task, as observed for the N1 association

interpretation in Experiment 4.

As we observed in Experiment 4, the results of the response times also showed a marginal main effect of *Sentence Type*, indicating that the participants responded faster to the probe words in the *experimental sentence* conditions compared to those in the *baseline sentence* conditions. We considered a possible reason for this pattern in our discussion of Experiment 4: a response time advantage only for the related words in the *experimental sentence* conditions. Such an advantage could lead to an overall advantage in processing the words in the *experimental sentence* conditions compared to the *baseline sentence* conditions.

6.4. General Discussion

We have examined whether the parser can consider the N1 association analysis at the N1 initially during the real-time processing of RC head association ambiguity. In Experiment 4, the results of the response times in the probe recognition task showed a significant interaction between *Sentence Type* and *N1-association Relatedness*, indicating that when the experimental sentences with RC head association ambiguity preceded the probe recognition task, the participants responded to the probe words related to the N1 association interpretation faster than they responded to the non-related words. This suggests that the participants considered the N1 association analysis prior to the recognition task. Furthermore, the results of the participants' head association choices showed a bias towards the N2 association. These results together suggest that, even after comprehenders consider the N1 association analysis initially, they may change their ultimate interpretation from the N1 to the N2 association (although they do not have to do so). This suggestion is consistent with the possibility of revision or reinterpretation of the RC head noun in the processing of head association ambiguity in Japanese RCs, as demonstrated in Experiments 2 and 3 (Chapter 5). Note that Experiment 1's off-line questionnaire, with its forced-choice task, was able to ask the participants only about their final interpretation (Chapter 4). In contrast, in Experiment 4, it

was possible to infer which interpretation (i.e., N1 or N2 association) the participants were considering at the point of the probe recognition task, while the comprehension check task showed their final choice for the RC head noun.

In Experiment 5, we predicted that, if unforced revision took place, the participants should respond to the words related to the N2 association interpretation faster, compared to the non-related words, in the probe recognition task for the *experimental sentence* conditions. Although we did not observe such an interaction of the two manipulations, the results of the comprehension check task showed a bias towards the N2 association interpretation. These results imply that the participants preferred the N2 association interpretation eventually, but the priming effect as a result of that interpretation was not robust enough to be detected at the time of the probe recognition task. Recall that in Experiment 4, we observed a robust priming effect as a result of the N1 association interpretation. This observation leads us to tentatively suggest that the N2 association interpretation takes longer to be established compared to the N1 association interpretation because it relies on the comprehenders' consideration of the coherence of the whole sentence, as suggested by Experiment 1's results. If this is the case, then the N2 association interpretation may not have been sufficiently established to produce a robust priming effect in the recognition task.

One more concern is that we observed a bias towards the N2 association interpretation in the comprehension check tasks in both experiments. Recall that, in contrast, off-line tasks in Experiment 1 (Chapter 4) and in a norming study for Experiment 2 (Chapter 5) showed the participants' preference for the N1 association interpretation. Because earlier studies have reported an off-line preference for the N2 association interpretation, a question arises as to why we observed this bias towards the N1 association interpretation in these two off-line tasks. What causes such differences in association preference? One possibility is related to the characteristics of the stimuli used in each study. In Experiment 1, there were two conditions, one of which might have made the participants biased towards the N1 association

interpretation as we discussed in Chapter 4. In the norming study for Experiment 2, two out of four conditions forced readers to adopt the N1 association interpretation only. That is, some stimuli were biased towards the N1 association interpretation in Experiment 1 and the norming study for Experiment 2 due to the design of the conditions, and thus the participants might have been biased towards the N1 association interpretation overall. On the other hand, in Experiments 4 and 5, there were two conditions, but the same sentences were used in both conditions of each item, because the two conditions were related only to the types of probe word (i.e., "related" or "non-related;" note also that the same experimental sentences were used in both experiments). In the two conditions, the N1 and N2 association interpretations were both viable, and thus the stimuli were less biased compared to Experiment 1 or the norming study in Experiment 2. This might have led to the participants' preference for the N2 association interpretation in Experiments 4 and 5.

6.5. Summary

This chapter has reported the results of two on-line probe recognition experiments. We have discussed how these results suggest that, even after the N1 association interpretation is established, reinterpretation of the RC head noun from the N1 to the N2 association can occur. We have also discussed why the N2 association interpretation would take longer to be established compared to the N1 association interpretation. A question remains as to what causes the bias towards the N2 association interpretation. Chapter 7 presents a corpus analysis that examines a possible factor in this bias: the structural frequency of the head association in RC production data.

CHAPTER 7

CORPUS ANALYSIS

7.1. Introduction

The goal of the corpus analysis in this chapter is to examine Research Question 4: Do production data of Japanese relative clauses (RCs) show a structural frequency bias towards the N2 association? The experimental results reported in this dissertation so far have not answered the question of why the parser would consider the N2 association analysis at the N2 in the real-time processing of RC head association ambiguity even when it is syntactically not necessary to do so. To address this question, a corpus analysis was carried out to answer Research Question 4. As seen in Chapter 2, corpus frequency has been discussed as one of the factors leading to RC attachment preferences in English and Spanish (e.g., Mitchell, Cuetos, & Corley, 1992; Mitchell, Cuetos, Corley, & Brysbaert, 1995). Our hypothesis is that if the N2 association interpretation is intended in production more frequently compared to the N1 association interpretation, comprehenders should experience the N2 association more often and thus be more likely to consider the N2 association analysis in their real-time processing. The corpus analysis presented in this chapter examines whether structural frequency could be a possible factor triggering unforced revision from the N1 to the N2 association analysis at the N2.

7.2. Method

Corpus

The Kyoto University Text Corpus was used for this analysis. It consists of Mainichi newspapers published in 1995 (http://nlp.ist.i.kyoto-u.ac.jp/EN/index.php?Kyoto%

20University%20Text%20Corpus). The corpus contains a total of 38,400 samples (one sample can contain more than one sentence). The Kyoto University Text Corpus was highly relevant for our purposes because in the corpus, the RC dependencies are specified. That is, when a RC modifies a complex noun phrase composed of the N1 and N2, the intended interpretation (i.e., N1 or N2 association) is annotated in the corpus.

Target samples

We focus on the samples containing the ambiguous RC structure. Out of the 38,400 samples in the corpus, 3,559 target samples were collected, using a PERL script that detected the dependent sequence of predicate (functioning as a RC) + N1 (as the first potential head noun) + *no* (as a genitive case marker) + N2 (as the second potential head noun). An example is given in (7.1).

(7.1) …欠かせない捜査の国際協力…
… [kakasenai] sôsa-no kokusai kyôryoku …
[$_{RC}$ indispensable] investigation-GEN international cooperation
'… the international cooperation of the investigation that is indispensable …'

In (7.1), the predicate *kakasenai* ('indispensable') is dependent either on the N1 *sôsa* ('investigation') or on the N2 *kokusai kyôryoku* ('international cooperation'). Hence, such a sample can be analyzed in terms of head association. That is, the N1 association is intended if the predicate (i.e., RC) is dependent on the N1. On the other hand, the N2 association is intended if the predicate depends on the N2.

Procedure

First, irrelevant samples were filtered out and excluded from further analyses if they met any of the criteria in (7.2), based on the information given in the corpus.

(7.2) Criteria for removing samples from the data set

a. A predicate for the RC is volitional (e.g., *ikô* (‘going to (somewhere)’)), conditional (e.g., *mireba* (‘(if someone) sees (something)’), or imperative (e.g., *seyo* (‘do (it)’)).
b. A noun for the N1 is formal (e.g., *monono* (‘though’)), temporal (e.g., *zenkaino* (‘last time’)), or adverbial (e.g., *tocyûno* (‘in progress’)).
c. A noun for the N2 is formal (e.g., *koto* (‘the fact (that)’), temporal (e.g., *naganen* (‘long years’)), numerical (e.g., *99%*), or adverbial (e.g., *tame* (‘for the purpose of (something)’)).

In the corpus, the samples are morphologically and syntactically annotated. For example, the types of predicate are specified (e.g., the present or past tense, conditional, imperative), and the nouns are also specified (e.g., common nouns, proper nouns, numerical nouns). The irrelevant samples were therefore possible to remove by using the criteria in (7.2) without looking at the content of each sample. Specifically, the samples were filtered out if they contained the types of predicates listed in (7.2a) because such predicates are not RCs but elements belonging to the preceding clauses. Samples containing nouns of the types listed in (7.2b-c) were also filtered out because such nouns cannot be clearly analyzed as head nouns for RCs. The total number of the remaining samples was 2,902.

Data treatment

First, the numbers of the N1 and N2 associations were counted in the initial data set of 3,559 target samples to observe the overall tendency of RC head association. Second, the numbers of the N1 and N2 associations were counted in the 2,902 sample data set that remained after the filtering procedure. A series of chi-square tests was performed to examine whether the number of N2 associations was higher than that of the N1 associations.

7.3. Results

First, Table 7-1 shows the overall results of the initial 3,559 samples.

Table 7-1: Head association frequencies out of 3,559 samples

Types of Head Association	Numbers of Samples (%)
N1 association	2,481 (69.7%)
N2 association	1,078 (30.3%)
Total	3,559 (100%)

Out of 3,559 samples, there were 2,481 instances of the N1 association (69.7%) and 1,078 instances of the N2 association (30.3%). This difference was significant ($\chi^2(1, N = 3559) = 553.08$, $p < .001$), indicating that overall, the N1 association was more frequently intended than the N2 association in the production data of the analyzed corpus.

Second, Table 7-2 presents the results of the 2,902 samples that were left after the data filtering.

Table 7-2: Head association frequencies out of 2,902 samples

Types of Head Association	Numbers of Samples (%)
N1 association	1,963 (67.6%)
N2 association	939 (32.4%)
Total	2,902 (100%)

There were 1,963 instances of the N1 association (67.6%) and 939 instances of the N2 association (32.4%), and the difference was significant ($\chi^2(1, N = 2902) = 361.33$, $p < .001$). This finding again suggests that the N1 association was intended in the production data more frequently than the N2 association.

7.4. Discussion

Research Question 4 asks: Do RC production data show a structural frequency bias towards the N2 association? The answer to this question is no because we observe no advantage for the N2 association; instead, the N1 association was intended more often, compared to the N2 association, in the corpus data that we analyzed. In Chapter 5, the eye-tracking data indicated that comprehenders considered the N2 association analysis at the N2 even when the N1 association analysis remained viable at that point. If an on-line N2 association preference at the N2 can be accounted for by structural frequency, there should be a strong bias towards the N2 association in production data. The current results, however, do not support this prediction.

Nakano (2015) analyzed the Balanced Corpus of Contemporary Written Japanese (BCCWJ) and presented some supporting evidence for the N2 association preference in production data. However, she concluded that both N1 and N2 association preferences existed, because the preference depended on the contexts preceding the target RC sentences. Thus, it is not the case that the N2 association is always preferred over the N1 association in production data.[36] Based on Nakano's (2015) conclusions and our corpus analysis results in this chapter, we suggest that a structural frequency bias cannot explain why comprehenders consider the N2 association analysis at the N2 instead of maintaining the N1 association analysis. While we were unable to find a strong bias towards the N2 association in the corpus that we analyzed, it is still possible that distributional factors may lead to the N2 association bias. As discussed in Chapter 2, the resolution of head association ambiguity in Japanese RCs is affected by a variety of factors: prosodic (phonetic-phonological) factors such as the length of the RC, the length of the N1 and the N2 (e.g., Hirose, Inoue, Fodor, & Bradley, 1998; Nakano & Kahraman, 2013); morpho-syntactic factors such as RC type (i.e., subject- or

[36] The fact that production data show there are both N1 and N2 association preferences is worth considering because both preferences have been reported in comprehension data. Which association is preferred in what contexts of comprehension and production is an issue for future investigation.

object-extracted), the matrix position of the complex NP (i.e., subject or object), the adjunctness of the N1 to the N2 (e.g., Uetsuki, 2006); semantico-pragmatic factors such as the semantic relationship between the RC and the N1 and between the N1 and the N2 (e.g., Aoyama & Inoue, 2005), and so on. Further research should examine the role of these factors using more data from a variety of corpora, not only written but also spoken.

7.5. Summary

In this chapter, we saw no strong frequency bias towards the N2 association in the analyzed corpus. Therefore, a question still remains as to why the parser considers the N2 association analysis at the N2 in the real-time processing of head association ambiguity in Japanese RCs. In Chapter 8, we will discuss our experimental and corpus results together and propose possible mechanisms that might answer this question.

CHAPTER 8

GENERAL DISCUSSION

8.1. Introduction

The goal of this dissertation is to explicate the nature of the mechanisms by which we humans comprehend sentences, with a particular focus on the phenomenon of head association ambiguity in Japanese relative clauses (RCs). The previous research on this phenomenon has suggested that comprehenders prefer the N1 association analysis initially at the N1, but then tend to revise it to settle on the N2 association analysis by the end of the sentence. In the present dissertation, we have inquired into why comprehenders consider the N2 association analysis at all when they do not have to revise their initial N1 association analysis because both interpretations are grammatically viable. As part of this inquiry, we investigated the time course of the N2 association analysis as well as the N1 association analysis. In this chapter, we first summarize the dissertation research's major findings, and we then discuss these findings' theoretical implications for the human language parsing mechanism (i.e., the parser).

8.2. Major Findings

Answer to Research Question 1

An off-line questionnaire experiment (Experiment 1 in Chapter 4) was conducted to answer Research Question 1: Can the parser choose the N2 association interpretation based on the coherence of the whole sentence? The results of Experiment 1 indicate that the answer to this question is yes. The results demonstrated that the parser establishes the N2 association interpretation based on the coherence of the whole sentence, particularly the implicit-causality relationship between the RC and the sentence-final main clause verbs.

Answer to Research Question 2

Two on-line eye-tracking reading experiments (Experiments 2 and 3 in Chapter 5) were carried out to answer Research Question 2: Can the parser consider the N2 association analysis prior to the end of the sentence during real-time processing? According to the results of Experiments 2 and 3, the answer to this question is yes. The results of Experiment 2 suggested that the parser considers the N2 association analysis at the latest at the N2. The results of Experiment 3 implied that the parser does not necessarily expect the N2 association analysis in advance, at the genitive case marker attached to the N1, before encountering the N2. Because our manipulation related to the N1s did not work as intended, we were not able to conclude that the parser's on-line consideration of the N2 association analysis at the N2 is affected by its initial commitment to the N1 association analysis.

Answer to Research Question 3

Two on-line probe recognition experiments (Experiments 4 and 5 in Chapter 6) were conducted to answer Research Question 3: Can the parser consider the N1 association analysis at the N1 initially when both the N1 and the N2 association analyses are available at the N2? The results of Experiment 4 suggested that the parser establishes the N1 association interpretation, which is based on the syntactic analysis in which the N1 is associated with the RC, by the end of the sentence. The results of Experiment 5, on the other hand, implied the possibility that although the parser considers the N2 association analysis at the N2 as suggested in Experiment 2, it may take longer to complete the establishment of the N2 association interpretation based on that syntactic analysis, compared to the N1 association interpretation. The reason for this difference in the time course of making the different analyses may be that the N2 association interpretation is result of considering the coherence of the whole sentence, as shown in Experiment 1.

Answer to Research Question 4

A corpus analysis (Chapter 7) was carried out to address the remaining question of why the parser would consider the N2 association analysis at the N2 by answering Research Question 4: Do RC production data show a structural frequency bias towards the N2 association? The answer to this question was no, based on the data in the corpus we analyzed. The results instead indicated a bias towards the N1 association, suggesting that structural frequency cannot explain the parser's on-line consideration of the N2 association analysis at the N2 as a result of revision from the N1 association analysis. Therefore, we must conclude that other factors are involved in such unforced (i.e., syntactically not required) revision.

8.3. Theoretical Implications

Considering the results reported in Chapters 4 through 7, this dissertation argues as follows. The results of earlier studies have shown an on-line preference for the N1 association analysis, and the results of our Experiment 4 suggested the establishment of the N1 association interpretation by the end of the sentence. It follows that the parser first associates the N1 with the RC immediately upon encountering the first potential head noun. The parser then revises the initial N1 association analysis and newly associates the N2 with the RC when the second potential head noun is introduced in the input, as demonstrated in Experiments 2 and 3. Furthermore, the results of Experiment 5 suggest that the parser may take longer to establish the N2 association interpretation based on the N2 association analysis, compared to the N1 association interpretation based on the N1 association analysis. The parser would need a longer time to establish the N2 association interpretation because it considers the coherence of the whole sentence, as shown in Experiment 1, to completely establish such an analysis.

In what follows, we focus on our finding of the parser's reconsideration of the RC head noun from the N1 to the N2 at the point of the N2 during on-line processing, and we discuss the theoretical implications of such unforced revision. We first consider this finding as counter

evidence for the Revision as Last Resort hypothesis. Second, we propose possible explanations for the phenomenon of unforced revision by considering cross-linguistic data in English and Japanese. Third, we return to the question of why the parser would perform revision when it is syntactically not necessary, and discuss possible mechanisms involved in such revision. Finally, we discuss what unforced revision tells us about parsing models.

Unforced revision as evidence against the Revision as Last Resort hypothesis

Our finding that revision from the N1 to the N2 association analysis does take place suggests that unforced revision exists in human language parsing. In the processing of RC head association ambiguity, the initial N1 association analysis is grammatical and thus does not have to be revised in terms of grammaticality. Hence, our finding is clear evidence against the Revision as Last Resort (RaLR) hypothesis (Fodor & Frazier, 1980). The RaLR hypothesis predicts that the initial grammatical N1 association analysis should be maintained unless it turns out to be incompatible with the incoming material. Contrary to this prediction, our results showed that the parser considers the N2 association analysis at the N2 even though the initial N1 association analysis can be retained because it is grammatically compatible with the incoming information.

Cross-linguistic perspectives on unforced revision

Our finding of unforced revision contrasts with the results of quite a few studies, on both Japanese and English, that have provided support for the RaLR hypothesis (e.g., Kamide & Mitchell, 1999, for Japanese; Schneider & Phillips, 2001; Sturt, Pickering, Scheepers, & Crocker, 2001, for English). We thus need an explanation that accounts for the difference between the results reported by the present dissertation and by these previous studies.

As reviewed in Chapter 2, the RaLR hypothesis has previously been challenged by Aoshima, Phillips, and Weinberg (2004). Providing evidence for unforced revision in the

processing of filler-gap dependencies in Japanese, they concluded that the RaLR hypothesis is too strong to explain the empirical data (see also Fodor & Inoue, 2000). Their claim was that the evidence makes it difficult to maintain the RaLR as the rigid principle originally proposed by Fodor and Frazier (1980). To account for when unforced revision is possible and when it is not possible, Aoshima, Phillips, and Weinberg (2004) proposed that cross-linguistic differences such as the position of the verb (e.g., head-final Japanese versus head-initial English) and the availability of overt scope markers (e.g., a question particle in Japanese) are involved. Our results support the argument that the availability of unforced revision interacts with lexico-semantic information such as animacy.

What is still puzzling is why unforced revision is observed in rather limited cases. Aoshima, Phillips, and Weinberg (2004) proposed that unforced revision is possible when the configuration leaves the initial analysis unconfirmed. Due to the head-final configuration of Japanese, the initial main-clause analysis cannot be confirmed until the main verb at the end of the sentence is encountered. In fact, the encounter with the embedded verb prior to the main verb makes it possible for the parser to switch from the initial main-clause analysis to the embedded-clause analysis. We argue that their proposal could account for our finding of unforced revision in the case of RC head association ambiguity. Our results showed that comprehenders tentatively associate the N1 with the preceding RC at the N1 and then revise the RC head noun from the N1 to the N2 at the N2, and that they do not decide on their final interpretation until they encounter the sentence-final main predicate. That is, even when the initial N1 association analysis satisfies the thematic relation between a RC and its head noun, the validity of the initial analysis is not confirmed until the sentence-final disambiguating information is received. We argue that this head-final configuration makes it possible for the parser to switch from the initial N1 association analysis to the N2 association analysis, and this is consistent with Aoshima, Phillips, and Weinberg's (2004) proposal regarding the varying availability of unforced revision.

In fact, there are some head-final configurations even in head-initial languages like English, and it has been suggested that unforced revision may be performed during the comprehension of these constructions. Consider, for example, the following NP in English:

(8.1) the recently divorced bishop's daughter

(Fodor & Inoue, 2000: 43)

In incrementally processing the NP in (8.1), readers would initially commit to the interpretation that the person who is recently divorced is the bishop. As Fodor and Inoue (2000) discussed, however, readers would revise this initial interpretation to reach the second interpretation, in which it is the bishop's daughter, not the bishop himself, who is recently divorced. Inoue and Fodor (1995) made the same claim for Japanese (see also Hirose, Inoue, Fodor, & Bradley, 1998; Hirose, 1999; Fodor & Inoue, 2000), as in the example of (8.2).

(8.2) kyokutanni sinsetuna gakusei-no imôto
extremely kind student-GEN sister
a. [extremely kind student]'s sister = sister of extremely kind student
b. [extremely kind] [student's sister] = extremely kind sister of student

(Inoue & Fodor, 1995: 23, (21))

Inoue and Fodor (1995) suggested that readers of this string would initially adopt the interpretation that a student is extremely kind, which, upon encountering the second noun, they would revise to the alternative interpretation that his/her sister is extremely kind. Taking these studies' findings together with those of this dissertation, we suggest that head-finality could be a key factor in determining when unforced revision is possible. Further research is needed to test this proposal, particularly research examining the processing of head-final constructions cross-linguistically.

Our proposal that head-finality may be a key factor in the availability of unforced revision is in line with the proposal that the parser exploits a *tentative attachment strategy* to process

head-final sentences in Japanese (Mazuka & Itoh, 1995). In such a strategy, performing any single revision is not costly, but a more complex revision process can become highly costly, for instance, when it involves lexical ambiguities, multiple revisions, and so on. According to this view, revising the initial N1 association analysis to the N2 association analysis in the processing of head association ambiguity should have little cost for the parser. In contrast, revising the incorrect N2 association analysis to the initial N1 association analysis would be more costly due to the involvement of multiple revisions, which would explain why readers experience difficulty in the process. The tentative attachment strategy can also account for Aoshima, Phillips, and Weinberg's (2004) observation that readers easily revised an initial main-clause analysis to the alternative embedded-clause analysis, which would be a single, low-cost revision, but experienced greater difficulty adopting the initial analysis again by revising the incorrect alternative, which would be a more complex, and more costly revision.

What triggers unforced revision?

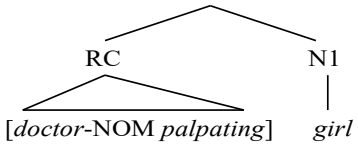
The question remains of why the parser performs unforced revision to consider the N2 association analysis at the N2 even though it does not have to revise the initial, grammatically viable N1 association analysis. What factors trigger unforced revision? We examined the relative frequency of the two structural analyses in Chapter 7, but the results did not show a bias towards the N2 association in the analyzed corpus. Therefore, structural frequency cannot explain the preference for the N2 association analysis as a result of revision from the N1 association analysis.

An alternative possibility is that unforced revision takes place due to processing strategies driven by head-finality such as the tentative attachment strategy (Mazuka & Itoh, 1995) discussed above. According to this strategy, the parser actively attaches the incoming material (e.g., N2) to the structure under construction (resulting in revision from the "tentative" N1 association analysis to the N2 association analysis), and evaluates the current analysis as it

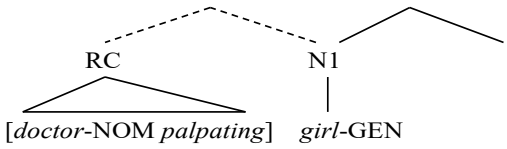
receives further incoming disambiguating information. Thus, revision from the N1 association analysis to the N2 association analysis follows a natural course for processing head-final structures.

Another possibility is related to general structure-building mechanisms for Japanese RC sentences. Specifically, these may include a *tree lowering* operation (Sturt & Crocker, 1996). In such an operation, the parser first associates the N1 with the preceding RC as in (8.3a). Upon encountering the genitive case marker attached to the N1, it *pushes down* the N1 to the modifier position, creating a complex NP headed by the N2 as in (8.3b). Finally, the parser associates the N2 (i.e., the complex NP) with the RC as in (8.3c).

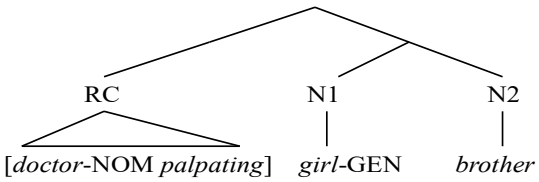
(8.3) a. *Associating the N1 with the RC (N1 association analysis)*



b. *Pushing down the N1 to a lower branch of the tree (unforced revision)*



c. *Associating the N2 (i.e., the complex NP) with the RC (N2 association analysis)*



On this view, as illustrated in (8.3a-c), the parser initially considers the N1 association analysis at the N1, then applies a tree-lowering operation resulting in what we have called "unforced" revision, and finally considers the N2 association analysis at the N2. If this is the case, it follows that revision from the N1 association analysis to the N2 association analysis is a natural transition in the processing of Japanese RCs with head association ambiguity. The implication is that the N2 association analysis may not necessarily reflect syntactic revision in the sense of the RaLR hypothesis.

Note, however, that both the tree-lowering view and the tentative attachment strategy would always predict a bias towards the N2 association analysis. Such a prediction would not be consistent with the results of our Experiment 3, which suggested that the parser may not consider the N2 association analysis in some cases, such as when the N2 is impossible as the RC head noun. Hence, we have to discuss what parsing models can capture the fact that the parser considers the N2 association analysis at some times but not at other times.

What unforced revision tells us about parsing models

The parsing models of particular interest to us are of the two types we discussed in Chapter 1: the serial modular models and the ranked-parallel interactive models. What does our finding of unforced revision tell us about these models? First, we discuss our results in terms of serial modular parsing. Serial models assume that the parser entertains only one analysis at a time. Our results suggest that the parser considers the N1 association analysis initially at the N1 and then revises it to the N2 association analysis at the N2. Furthermore, our results imply that depending on the animacy information of the N2, the parser does or does not consider the N2 association analysis at the N2. This implication is not consistent with the "deterministic" serial parser view, which assumes that only one analysis can be considered at any ambiguous region, following parsing principles insensitive to lexico-semantic information such as animacy. Alternatively, the "probabilistic" serial model

(Lewis, 2000) assumes that at an ambiguous point, the parser can consider one analysis at some times and another at other times, according to the probability of each possible analysis. Such a model could therefore account for our finding that reconsideration of the RC head noun from the N1 to the N2 sometimes happens, unlike the "deterministic" models.

Modular models assume that different kinds of information are used at different times during the construction of a syntactic analysis and the initial stage of parsing is driven exclusively by syntactic information. Our results suggest that the parser's on-line consideration of the N2 association analysis at the N2 is driven by other kinds of information than syntax or grammaticality, because revision from the N1 association analysis to the N2 association analysis is syntactically not required. Moreover, the parser's consideration of the N2 association analysis depends on the animacy of the N2. These findings suggest that the parser's on-line construction of the N2 association analysis at the initial stage is dependent on lexico-semantic information such as animacy. This is inconsistent with a "syntax first" modular parser like the strictly staged *Garden-path Model* because animacy is a different level of information from syntax, and thus assumed by such models to have no immediate impact on the initial stage of parsing.

Second, we discuss our results in terms of ranked-parallel interactive parsing. Ranked-parallel models assume that more than one analysis is considered simultaneously, and the most motivated analysis is ranked most highly. Our results imply that after the N1 association analysis is considered at the N1, the N2 association analysis is ranked higher at the N2 compared to the N1 association analysis. Thus, reconsideration of the RC head noun from the N1 to the N2 reflects such re-ranking.

Interactive models assume that multiple sources of information are used during on-line consideration of the analyses. Our results suggest that because the initial N1 association analysis is perfectly grammatical, sources of information other than grammaticality are involved in the parser's consideration of the N2 association analysis at the N2. Relevant

sources of information are suggested by Predicate Proximity (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) and Main Assertion Principle (Traxler & Frazier, 2008). The N2 is the head noun of the complex NP with the N1 as an adjunct. Therefore, compared to the N1, the N2 is both linearly more proximate to the main predicate and informationally more important to interpret the main assertion, i.e., the content of the main clause. Based on such characteristics, these principles make the RC more likely to modify the N2 than the N1. These interactive accounts are also in line with our finding that the parser's consideration of the N2 association analysis at the N2 is dependent on the animacy information of the N2. Our results can be explained in this way: the parser considers the N2 association analysis at the N2 by interactively using various kinds of information in addition to the syntactic information during on-line processing.

In conclusion, our finding of revision from the N1 to the N2 association analysis in the processing of Japanese RCs tells us that, in a plausible model, the human language parsing mechanism must possess three characteristics. First, it permits unforced revision (i.e., syntactically not required consideration of an alternative analysis). Second, it is probabilistic (i.e., at each point, possible parses are evaluated according to their probability). Third, it is interactive (i.e., on-line evaluation of each possible parse is based on multiple sources of information available at the point in question). Our results do not provide grounds for a decisive conclusion as to whether serial or ranked-parallel models are more plausible as the human language parsing mechanism, because our results do not refute the possibility of a "probabilistic" serial parser. These three characteristics, however, are all consistent with a ranked-parallel interactive parsing model. Hence, our results, along with those of a number of recent studies on sentence parsing (see Chapter 1), help make the case that a ranked-parallel parser is more plausible, than a serial parser, to account for human language parsing.

8.4. Summary

In this chapter, we have discussed the results reported in the present dissertation and argued that the human language parsing mechanism permits unforced revision, contrary to the RaLR hypothesis, and is driven by probabilistic and interactive processing. As one possible reason that unforced revision is observed in rather limited cases, we have proposed that head-finality might be a key factor in the availability of unforced revision on the basis of cross-linguistic evidence from English as well as Japanese. We have also discussed the possibility that other factors such as the tentative attachment strategy, the tree-lowering operation, the Predicate Proximity, and the Main Assertion Principle could be involved in the availability of unforced revision. Finally, we have argued that our results may be captured better by the ranked-parallel interactive parsing models, which is in line with a number of recent psycholinguistic studies on sentence processing.

CHAPTER 9

CONCLUSIONS

9.1. Introduction

In this concluding chapter, we first summarize the dissertation's major findings. We then point out some limitations and offer suggestions for future research.

9.2. Findings

The goal of this dissertation was to explicate the mechanism of how people comprehend sentences (i.e., the mechanism that we call the parser), with a particular focus on head association ambiguity in Japanese relative clause (RC) processing. The previous research on this phenomenon has shown that Japanese comprehenders initially show a preference for N1 association analysis at the N1, but eventually prefer the N2 association analysis at the end of the sentence. These studies have provided clear evidence for comprehenders' initial commitment to the N1 association analysis, but little information about the time course of the process in which the parser arrives at the N2 association analysis. The present dissertation therefore investigated the time course of the N2 association analysis as well as the N1 association analysis by examining four research questions through a series of off-line and on-line experiments and a corpus analysis. First, an off-line questionnaire experiment (Experiment 1 in Chapter 4) examined Research Question 1: Can the parser choose the N2 association interpretation based on the coherence of the whole sentence? The results suggested that the parser does establish the N2 association interpretation based on the coherence of the whole sentence, particularly the relationship between the RC and the main clause verbs. Second, two on-line eye-tracking experiments (Experiments 2 and 3 in Chapter

5) investigated Research Question 2: Can the parser consider the N2 association analysis prior to the end of the sentence during real-time processing? The results of Experiment 2 demonstrated that the parser considers the N2 association analysis at the N2, and those of Experiment 3 suggested that the parser does not necessarily expect the N2 association analysis in advance, that is, at the genitive case marker attached to the N1. Third, two on-line probe recognition experiments (Experiments 4 and 5 in Chapter 6) tackled Research Question 3: Can the parser consider the N1 association analysis at the N1 initially when both the N1 and the N2 association analyses are available at the N2? The results of Experiment 4 demonstrated that the parser establishes the N1 association interpretation, which is based on the syntactic analysis in which the N1 is associated with the RC, by the end of the sentence. On the other hand, the results of Experiment 5 implied that the N2 association interpretation, based on the syntactic analysis in which the N2 is associated with the RC, might take longer to construct and establish, compared to the N1 association interpretation. Finally, a corpus analysis (Chapter 7) examined Research Question 4: Do RC production data show a structural frequency bias towards the N2 association? The results from the analyzed corpus showed no bias towards the N2 association, suggesting that structural frequency cannot motivate revision from the N1 to the N2 association analysis, and therefore other factors must be involved in the parser's reconsideration of the RC head noun.

We have argued that, taken together, these results support four conclusions. First, revision that is syntactically not required exists in human language parsing. Such unforced revision is clear evidence against the Revision as Last Resort hypothesis because the initial N1 association analysis can be maintained in terms of grammaticality, but our results showed that it can nevertheless be revised at the N2. Second, the parser's reconsideration of the RC head noun from the N1 to the N2 is consistent with the tree-lowering operation and the tentative attachment strategy. Thus, revision from the N1 association analysis to the N2 association analysis at the N2 is in accord with a natural way of processing head-final structures such as

Japanese RCs with head association ambiguity. Third, unforced revision is observed cross-linguistically but in rather limited cases. Because unforced revision appears to be limited to the processing of head-final constructions such as head association ambiguity in Japanese RCs, head-finality may be a key factor in its availability. Finally, our results are consistent with the parsing models that posit a "probabilistic," not "deterministic," serial parser; a ranked-parallel parser; and an interactive, not modular or strictly staged, parser. The results suggested that at the N2, the parser maintains the N1 association analysis at certain times such as when the N2 is impossible as the RC head noun, and considers the N2 association analysis at other times such as when the N2 is also a viable head noun. Such a manner of proceeding can be captured as "probabilistic" serial processing but not as "deterministic" serial processing. The results of the parser's reconsideration of the RC head noun during on-line parsing can be captured as re-ranking in ranked-parallel processing, and such reconsideration can be motivated by interactive processing, but not by modular processing. On this basis, we argued that a ranked-parallel interactive parser captures our results better than a serial modular parser, which is consistent with a number of recent studies on sentence processing.

In conclusion, the way we comprehend sentences, that is, the human sentence parsing mechanism, includes the following characteristics:

(9.1) *Characteristics of the human sentence parsing mechanism*

a. It decides on its final interpretation based on whole sentence coherence.
b. It permits unforced (i.e., syntactically not required) revision.
c. It interacts with syntactic head-finality of languages or constructions in a language to apply such operations as unforced revision.
d. It employs the tree-lowering operation and the tentative attachment strategy in the processing of head-final constructions such as Japanese RCs with head association ambiguity.

These characteristics should be further examined along the lines suggested for future research in Section 9.3.

9.3. Limitations and Suggestions for Future Research

This dissertation's demonstration of the existence of unforced revision in human language parsing leaves a number of important problems for future research. What follows is a series of suggestions for further studies, considering the limitations of the present dissertation.

Suggestion 1: Examine what factors other than head-finality are involved in the availability of unforced revision.

In this dissertation, we have found that unforced revision is involved in the processing of head association ambiguity in Japanese RCs. Based on this finding, we expect that such revision can be observed in equivalent phenomena in other head-final languages and head-final constructions as well. That is, it should be possible to observe both on-line preference for the N1 association analysis and off-line preference for the N2 association analysis in head-final languages and constructions. For example, Korean has a corresponding construction with the same word order (RC+N1+N2). In Korean, however, it is reported that the N1 association analysis is preferred in off-line experiments (e.g., Kang, Speer, & Nakayama, 2016; cf. Jun, 2003, for the off-line N2 association preference[37]). Chinese is a head-initial language with the same word order as English (i.e., subject-verb-object), but it has a parallel construction (RC+N1+N2) to the Japanese ambiguous RC. In Chinese, the N1 association analysis is preferred in off-line experiments as well as on-line experiments (e.g., Shen, 2006). Against our expectation, the experimental results from Korean and Chinese are not consistent with unforced revision. Note, however, that the RC structures are different in

[37] No relevant on-line data from Korean were found in the literature. If the N1 association analysis is preferred on-line and, as Jun (2003) reported, the N2 association analysis is preferred off-line, we could argue for unforced revision in the processing of Korean as well. Hence, RC head association ambiguity in Korean is worth examining with on-line techniques in future research.

Japanese, Korean, and Chinese. In Korean, a special ending attaches to the RC verb, which signals that the clause in question is a RC before comprehenders encounter the N1. In Chinese, a relativizer follows the RC, which, again, tells comprehenders that the current clause is a RC before they reach the N1. In Japanese, there is neither a relativizer nor a special ending on the RC verb, and consequently comprehenders have no way of knowing that the clause in question is a RC until they encounter the N1. These language-particular characteristics may affect the availability of unforced revision. RC head association ambiguity with head-final word order, RC+N1+N2, in other languages than Japanese is worth (re-)examining to narrow down the factors motivating unforced revision from the N1 to the N2 association analysis.

Suggestion 2: Investigate whether unforced revision is observed in the resolution of other relevant kinds of global structural ambiguity.

As we have discussed, unforced revision is found not only in head-final Japanese but also in head-final constructions in head-initial English. Despite this cross-linguistic evidence, such revision can be observed in rather limited cases. If unforced revision were available in every global structural ambiguity in a head-final language or construction, we could always observe the on-line preference for the initial analysis and the eventual preference for the alternative analysis. As discussed in Suggestion 1, however, unforced revision is not supported by the results from studies of RC head association ambiguity in Korean or Chinese. We also pointed out that the RC structures in Japanese are different from those in Korean or Chinese. Therefore, a possibility remains that while unforced revision exists, its availability can be blocked by the characteristics of particular languages or constructions. The examination of different kinds of global structural ambiguity, other than Japanese RC head association ambiguity, would contribute to narrowing down the factors involved in the availability or non-availability of unforced revision. For instance, left/right-branching modifier ambiguities examined by Inoue and Fodor (1995) for Japanese and Fodor and Inoue (2000) for English are

worth investigating further from the perspective of unforced revision.

Suggestion 3: Investigate whether the predictions of the unforced revision hypothesis are borne out in other head-final languages and constructions.

We have proposed that head-finality may be a key factor in the availability of unforced revision. If this is the case, then unforced revision should be observable in other relevant head-final languages and constructions. As discussed in Chapter 8, unforced revision is observed even in head-initial English when the construction being processed is head-final such as *the recently divorced bishop's daughter*, which is consistent with this prediction. As discussed in Suggestion 1, however, unforced revision is apparently not involved in the head-final RC constructions with head association ambiguity in head-initial Chinese or head-final Korean, which is not consistent with the prediction. Further cross-linguistic and cross-constructional examinations of the unforced revision hypothesis would contribute to explicating the universal and language- or construction-particular nature of human language parsing.

Suggestion 4: Investigate the validity of the serial and ranked-parallel models of parsing by making use of the RC head association ambiguity phenomenon in Japanese.

In the present dissertation, we have not been able to tease apart the serial and ranked-parallel models of parsing. Our study was the first to use a (post-sentential) probe recognition technique to examine RC head association ambiguity in Japanese. If we can design a relevant (intra-sentential) probe recognition task, the two models could be teased apart. Serial models assume that only one analysis is entertained at a time, while (ranked-)parallel models assume that more than one analysis is considered simultaneously. On these assumptions, the two models make different predictions about which analysis the parser would consider at the point of the N2. Serial models predict that the parser considers either

the N1 association analysis or the N2 association analysis, but not both, at the N2, whereas parallel models predict that the parser considers both the N1 and the N2 association analyses at the N2. A reading task that presents a probe recognition task immediately after the N2 could test these predictions.[38] Serial models predict faster response times to a probe word related to the N1 association interpretation, compared to a non-related word, when the N1 association analysis is considered but not when the N2 association is considered. Parallel models always predict faster response times to related probe words because at the N2, both analyses are considered. Serial models also predict faster response times to probe words related to the N2 association interpretation only when the N2 association analysis is considered. Meanwhile, parallel models again predict faster response times in both cases. Testing these predictions could tell us whether the serial or the parallel models are more plausible.

[38] Recall that in the present dissertation, we were not able to obtain evidence for the parser's on-line consideration of the N1 association analysis at the N1 because our experimental manipulation did not work as intended. An intra-sentential probe recognition task might be able to address this issue. If the parser considers the N1 association analysis at the N1, it should show faster response times to a word related to the N1 association interpretation, compared to a non-related word, when the word appears immediately after receiving the N1. Furthermore, if the parser expects the N2 association analysis at the genitive case marker attached to the N1, faster response times should not be observed when a word related to the N1 association interpretation is presented immediately after the genitive case marker appears. Examining these predictions is an intriguing direction for future research.

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APPENDICES

Appendix A
Target Stimuli in Experiment 1

Conditions (a) and (b) correspond to the *Causal* and *Neutral* conditions, respectively. (Items 6, 11, 12, 13, and 15 were excluded for use and analysis.)

Item numbers	Conditions	Stimuli
1	a	転んだ俳優の監督が骨折した。
	b	転んだ俳優の監督が笑った。
2	a	脱税した選手の教官がばれた。
	b	脱税した選手の教官がくつろいだ。
3	a	酔った秘書の社長が倒れた。
	b	酔った秘書の社長がささやいた。
4	a	遅刻した児童の教師が謝った。
	b	遅刻した児童の教師が留学した。
5	a	頑張った患者の医者が疲れた。
	b	頑張った患者の医者が歌った。
6	a	成功した社員の部長が喜んだ。
	b	成功した社員の部長が走った。
7	a	病んだ翻訳家の編集者が入院した。
	b	病んだ翻訳家の編集者がしゃべった。
8	a	逃げた依頼人の弁護士が捕まった。
	b	逃げた依頼人の弁護士が働いた。
9	a	驚いた探偵の助手が黙った。
	b	驚いた探偵の助手が料理した。
10	a	失恋した政治家の評論家が悲しんだ。
	b	失恋した政治家の評論家が拍手した。
11	a	けんかした写真家のモデルが仲直りした。
	b	けんかした写真家のモデルが泳いだ。
12	a	遊んだ芸能人のファンが楽しんだ。
	b	遊んだ芸能人のファンが祈った。
13	a	感動した旅行客のガイドが泣いた。
	b	感動した旅行客のガイドが歩いた。
14	a	火傷した補佐官の運転手が療養した。
	b	火傷した補佐官の運転手が挨拶した。
15	a	挫折した大佐の兵士が落ち込んだ。
	b	挫折した大佐の兵士が踊った。
16	a	助かった大使の通訳が安堵した。
	b	助かった大使の通訳が旅行した。

Appendix B
Norming Study I (Experiment 1)

What follows is the instructions to the respondents for the questionnaire used in the first norming study (Norming Study I) in Experiment 1.

質問紙１

氏名：＿＿＿＿＿＿＿＿＿＿　（非公開）

次の文の意味が妥当であるか（あり得るか）を６段階で判断してください。

１「全然妥当でない」―２「妥当でない」―３「どちらかと言えば妥当でない」―４「どちらかと言えば妥当である」―５「妥当である」―６「とても妥当である」

該当する番号を○で囲んで答えてください。
例えば、「かぼちゃが酒を飲んだ。」を考えてください。おとぎ話のような世界ではあり得るかもしれませんが、現実世界ではあり得ません。この場合、評価は１「全然妥当でない」になるでしょう。
似たような文がありますが、どちらの方が妥当であるかを判断するのではなく、以下１文ずつ独立に妥当性を判断してください。

Item example:

		妥当性の判断					
1.	俳優が転んだ。	1	2	3	4	5	6

Appendix C
Norming Study II (Experiment 1)

The following is the instructions to the informants for the questionnaire of the second norming study (Norming Study II) in Experiment 1.

質問紙２

氏名：＿＿＿＿＿＿＿＿＿＿　（非公開）

次の出来事のペア（出来事 A→出来事 B）に因果関係があるかどうかを６段階で判断してください。

１「全然因果関係がない」―２「因果関係がない」―３「どちらかと言えば因果関係がない」―４「どちらかと言えば因果関係がある」―５「因果関係がある」―６「とても因果関係がある」

該当する番号を○で囲んで答えてください。
例えば、出来事 A「運転した」→ 出来事 B「退職した」を考えてください。「運転した」ので「退職した」ということにはなりません。この場合、評価は１「全然因果関係がない」になるでしょう。
似たようなペアがありますが、どちらの方が因果関係があるかを判断するのではなく、以下１ペアずつ独立に因果関係を判断してください。

Item example:

	出来事 A → 出来事 B	因果関係の判断					
1.	「転んだ」 「骨折した」	1	2	3	4	5	6

Appendix D
Target Stimuli in Experiment 2

Conditions (a), (b), (c), and (d) correspond to the *N2-association incompatible* + *N1-association neutral*, *N2-association incompatible* + *N1-association typical*, *N2-association compatible* + *N1-association neutral*, and *N2-association compatible* + *N1-association typical* conditions, respectively.

Item numbers	Conditions	Stimuli
1	a	警察が今まさに捜し回っている少年の女友達が刑務所で服役している。
	b	警察が今まさに捜し回っている犯人の女友達が刑務所で服役している。
	c	警察が今まさに捜し回っている少年の女友達がホテルに泊まっている。
	d	警察が今まさに捜し回っている犯人の女友達がホテルに泊まっている。
2	a	バスガイドがちょうど今引率している少年の姉が自宅で寝ていた。
	b	バスガイドがちょうど今引率しているツアー客の姉が自宅で寝ていた。
	c	バスガイドがちょうど今引率している少年の姉が携帯でメールしていた。
	d	バスガイドがちょうど今引率しているツアー客の姉が携帯でメールしていた。
3	a	コーチが競技場で指導している少年の先輩が観客席で見守っていた。
	b	コーチが競技場で指導している陸上選手の先輩が観客席で見守っていた。
	c	コーチが競技場で指導している少年の先輩がビデオに録画していた。
	d	コーチが競技場で指導している陸上選手の先輩がビデオに録画していた。
4	a	塾講師が今まさに怒鳴りつけている少年の妹が学食で食事していた。
	b	塾講師が今まさに怒鳴りつけている男子学生の妹が学食で食事していた。
	c	塾講師が今まさに怒鳴りつけている少年の妹が教室で泣いていた。
	d	塾講師が今まさに怒鳴りつけている男子学生の妹が教室で泣いていた。
5	a	医師がたった今触診している少女の兄が売店で買い物していた。
	b	医師がたった今触診している患者の兄が売店で買い物していた。
	c	医師がたった今触診している少女の兄が椅子でじっとしていた。
	d	医師がたった今触診している患者の兄が椅子でじっとしていた。
6	a	芸能記者が玄関先で取材している少女の祖父がお寺に出かけている。
	b	芸能記者が玄関先で取材しているアイドルの祖父がお寺に出かけている。
	c	芸能記者が玄関先で取材している少女の祖父がカメラに緊張している。
	d	芸能記者が玄関先で取材しているアイドルの祖父がカメラに緊張している。
7	a	教師がまさに今問い詰めている少女の弟が食堂で皿洗いしている。
	b	教師がまさに今問い詰めている女子高生の弟が食堂で皿洗いしている。
	c	教師がまさに今問い詰めている少女の弟が机で突っ伏している。
	d	教師がまさに今問い詰めている女子高生の弟が机で突っ伏している。
8	a	新聞記者がまさに今責め立てている少女の男友達が待合室で待機していた。

	b	新聞記者がまさに今責め立てている大臣の男友達が待合室で待機していた。
	c	新聞記者がまさに今責め立てている少女の男友達がパイプ椅子に座っていた。
	d	新聞記者がまさに今責め立てている大臣の男友達がパイプ椅子に座っていた。
9	a	作家が書斎で面談している男性の祖母が北極に旅行している。
	b	作家が書斎で面談している編集者の祖母が北極に旅行している。
	c	作家が書斎で面談している男性の祖母がアームチェアに腰掛けている。
	d	作家が書斎で面談している編集者の祖母がアームチェアに腰掛けている。
10	a	デザイナーが事務所で叱責している男性の元カノが離島でバカンスしていた。
	b	デザイナーが事務所で叱責している助手の元カノが離島でバカンスしていた。
	c	デザイナーが事務所で叱責している男性の元カノがソファで貧乏揺すりしていた。
	d	デザイナーが事務所で叱責している助手の元カノがソファで貧乏揺すりしていた。
11	a	強盗がちょうど今脅している男性の女上司が自宅で寝ていた。
	b	強盗がちょうど今脅している銀行員の女上司が自宅で寝ていた。
	c	強盗がちょうど今脅している男性の女上司がデスクで身震いしていた。
	d	強盗がちょうど今脅している銀行員の女上司がデスクで身震いしていた。
12	a	判事が法廷で諭している男性の姪がアパートで料理していた。
	b	判事が法廷で諭している容疑者の姪がアパートで料理していた。
	c	判事が法廷で諭している男性の姪が席で静聴していた。
	d	判事が法廷で諭している容疑者の姪が席で静聴していた。
13	a	機長がキャビンで捜している女性の元カレがビーチで泳いでいた。
	b	機長がキャビンで捜している客室乗務員の元カレがビーチで泳いでいた。
	c	機長がキャビンで捜している女性の元カレがトイレで隠れていた。
	d	機長がキャビンで捜している客室乗務員の元カレがトイレで隠れていた。
14	a	助産師が院内で呼び止めている女性の父親が車で休んでいた。
	b	助産師が院内で呼び止めている妊婦の父親が車で休んでいた。
	c	助産師が院内で呼び止めている女性の父親がベンチであくびした。
	d	助産師が院内で呼び止めている妊婦の父親がベンチであくびした。
15	a	消防士がまさに今救助している女性の上司が対策本部で心配していた。
	b	消防士がまさに今救助している被災者の上司が対策本部で心配していた。
	c	消防士がまさに今救助している女性の上司が大声で感謝していた。
	d	消防士がまさに今救助している被災者の上司が大声で感謝していた。
16	a	看護師がたった今手当てしている女性の甥が受付で待っていた。
	b	看護師がたった今手当てしている負傷者の甥が受付で待っていた。
	c	看護師がたった今手当てしている女性の甥がベッドで横たわっていた。
	d	看護師がたった今手当てしている負傷者の甥がベッドで横たわっていた。
17	a	運転手がちょうど今降ろそうとしている婦人の子どもが病院で入院している。
	b	運転手がちょうど今降ろそうとしている乗客の子どもが病院で入院している。
	c	運転手がちょうど今降ろそうとしている婦人の子どもがシートではしゃいでいる。
	d	運転手がちょうど今降ろそうとしている乗客の子どもがシートではしゃいでいる。

18	a	映画監督が現場で叱っている婦人の息子が幼稚園で遊んでいた。
	b	映画監督が現場で叱っている助監督の息子が幼稚園で遊んでいた。
	c	映画監督が現場で叱っている婦人の息子がカメラに映っていた。
	d	映画監督が現場で叱っている助監督の息子がカメラに映っていた。
19	a	ゴルファーがコースに連れ回している婦人の後輩がレストランで涼んでいた。
	b	ゴルファーがコースに連れ回しているキャディーの後輩がレストランで涼んでいた。
	c	ゴルファーがコースに連れ回している婦人の後輩が小石につまずいた。
	d	ゴルファーがコースに連れ回しているキャディーの後輩が小石につまずいた。
20	a	部長が飲み屋で説教している婦人の婚約者がマンションで片付けしていた。
	b	部長が飲み屋で説教している係長の婚約者がマンションで片付けしていた。
	c	部長が飲み屋で説教している婦人の婚約者がテーブルで居眠りしそうだった。
	d	部長が飲み屋で説教している係長の婚約者がテーブルで居眠りしそうだった。
21	a	弁護士が今まさに事情聴取している紳士の長女が海外に留学している。
	b	弁護士が今まさに事情聴取している依頼人の長女が海外に留学している。
	c	弁護士が今まさに事情聴取している紳士の長女が緊張に震えている。
	d	弁護士が今まさに事情聴取している依頼人の長女が緊張に震えている。
22	a	カメラマンがスタジオで撮影している紳士の親が控え室で休憩していた。
	b	カメラマンがスタジオで撮影しているモデルの親が控え室で休憩していた。
	c	カメラマンがスタジオで撮影している紳士の親が笑顔で立っていた。
	d	カメラマンがスタジオで撮影しているモデルの親が笑顔で立っていた。
23	a	検察がたった今尋問している青年の彼女が神社にお参りしている。
	b	検察がたった今尋問している被告人の彼女が神社にお参りしている。
	c	検察がたった今尋問している青年の彼女が無言で回想している。
	d	検察がたった今尋問している被告人の彼女が無言で回想している。
24	a	保育士が園庭で呼びかけている青年の母親が工場で仕事していた。
	b	保育士が園庭で呼びかけている園児の母親が工場で仕事していた。
	c	保育士が園庭で呼びかけている青年の母親が花壇で水やりしていた。
	d	保育士が園庭で呼びかけている園児の母親が花壇で水やりしていた。

Appendix E
Norming Study I (Experiment 2)

For the first norming study (Norming Study I) in Experiment 2, the following instructions were used for the questionnaire.

この度は、調査へのご協力ありがとうございます。
これはあなたの言語能力を測るものではありません。調査で得られた個人情報は厳密に扱い、また結果を公表する際には匿名で行うなど、あなたのプライバシーを侵害することは一切ありません。

課題：
文を読んで、文の内容に基づいて二択の質問に答えてください。

手順：
１．文が呈示されたら黙読をしてください。時間をかけても構いませんが、正確に読んでください。
２．読み終えたら、二択の質問に回答してください。一つの選択肢を選んで、「次へ」をクリックしてください。
（以下、１と２の繰り返しです）

注意：
回答中、絶対に「戻る」ボタンは押さないでください。エラーが起きてしまいます（データが正常に取れなくなってしまいます）。
（誤って「戻る」をクリックしてしまった場合は、戻った画面の「次へ」をすぐにクリックし、回答を続けてください）

文は全部で 60 個あります。
最後の文の質問に回答し終えたら、「送信」をクリックしてください。
「回答を記録しました」と出たら、正常に終わったことになります。

Item example:

警察が今まさに捜し回っている少年の女友達が刑務所で服役している。

警察が今まさに捜し回っているのは誰ですか？

少年
女友達

Appendix F

Norming Study II (Experiment 2)

The following is the instructions used in the questionnaire of the second norming study (Norming Study II) in Experiment 2.

これから、７６個の文を読んでいただき、個々の文が表現する事柄がどれだけ現実にあり得そうか、つまり典型的だと感じるかの度合い（典型度）を、「１」（全く典型的でない）～「５」（とても典型的である）の５段階で評定していただきます。

例えば、「バス運転手がバスを掃除している。」がとても典型的だと思ったら「５」を選んでください。 また例えば、「バス運転手が飛行機を操縦している」が全く典型的でないと思ったら「１」を選んでください。

１から５の数字は、意図的にまんべんなく使うように配慮する必要はありません（同じ数字が特に多く使われてもかまいません)。あまり悩まずに、できるだけ素早く直感で判断していただければ結構です。

どうぞよろしくお願いします。

注意：ページをめくったら、絶対に、前のページに戻らないでください。

Item example:

１．警察が今まさに少年を捜し回っている。

全く典型的でない　１　２　３　４　５　とても典型的である

Appendix G
Norming Study III (Experiment 2)

What follows is the instructions used in the questionnaire for the third norming study (Norming Study III) in Experiment 2.

これから、５２個の「Y の Z」という名詞句をご覧いただきます。「Y の Z」という表現にはいろいろな意味解釈がありえますが（例えば、「僕の家」であれば、「僕が所有している家」、「僕が建てた家」、「僕が販売を担当している家」など)、今回はこれが「Y である Z」という同格として「容認可能か」を、「１」（可能でない)、「２」((最初に思いついた解釈ではないが、）それも可能である)、「３」（最初に思いついた自然な解釈である）の３段階で評定していただきます。

例えば、「女性のタクシー運転手」が、女性であるタクシー運転手、つまり女性はタクシー運転手、という同格としての解釈が自然だと思ったら「３」を選んでください。 また例えば、「男性の嫁」が、男性である嫁、つまり男性は嫁、という同格としての解釈が可能でないと思ったら「１」を選んでください（この場合、男性がいて、その人の嫁、という意味解釈になると思います)。

１から３の数字は、意図的にまんべんなく使うように配慮する必要はありません（同じ数字が特に多く使われてもかまいません)。 あまり悩まず、できるだけ素早く直感で判断していただければ結構です。 どうぞよろしくお願いします。

注意：一度回答し終わった設問は、後から戻って再検討しないでください。

Item example:

１．少年の女友達

同格として可能でない	同格としても解釈できる	同格としての解釈が自然である
1	2	3

Appendix H
The Results of the First Three Regions (Experiment 2)

Table H-1 shows the means (and SEs) of the four measures in each of the first three regions in Experiment 2, and Table H-2 the results from the best-fit LME models.

Table H-1: The means (and SEs) of four eye-movement measures in the first three regions (Experiment 2)

Measures	RC Subject *police-NOM*	RC Adverb *right now*	RC Verb *searching for*
First-pass (with regressions)			
N2-association incompatible + N1-association neutral	309 (22)	323 (21)	367 (23)
N2-association incompatible + N1-association typical	282 (19)	310 (19)	378 (27)
N2-association compatible + N1-association neutral	339 (21)	316 (15)	351 (20)
N2-association compatible + N1-association typical	334 (26)	303 (23)	362 (23)
Regression-path			
N2-association incompatible + N1-association neutral	–	406 (28)	450 (29)
N2-association incompatible + N1-association typical	–	418 (30)	472 (34)
N2-association compatible + N1-association neutral	–	411 (32)	463 (30)
N2-association compatible + N1-association typical	–	398 (28)	468 (27)
Second-pass			
N2-association incompatible + N1-association neutral	248 (44)	408 (77)	514 (72)
N2-association incompatible + N1-association typical	346 (67)	477 (83)	558 (84)
N2-association compatible + N1-association neutral	287 (56)	450 (72)	629 (86)
N2-association compatible + N1-association typical	311 (65)	410 (78)	520 (82)
Regressions-out			
N2-association incompatible + N1-association neutral	–	0.15 (0.03)	0.14 (0.03)
N2-association incompatible + N1-association typical	–	0.20 (0.04)	0.15 (0.04)
N2-association compatible + N1-association neutral	–	0.14 (0.03)	0.14 (0.03)
N2-association compatible + N1-association typical	–	0.17 (0.03)	0.15 (0.03)

Note: A hyphen (–) indicates data irrelevant for the sentence-initial region.

(continued)

Table H-2: The statistical results from the best-fit models for four eye-movement measures in the first three regions (Experiment 2)

Measures	RC Subject				RC Adverb				RC Verb			
	police-NOM				*right now*				*searching for*			
First-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	305.87	22.80			310.36	18.88			362.32	21.53		
N2Compatibility	39.31	19.01	2.07	.04*	-8.81	14.09	-0.63		-14.55	17.31	-0.84	
N1Typicality	14.20	17.63	0.81		12.68	14.08	0.90		-11.89	18.11	-0.66	
Interaction	-9.67	35.67	-0.27		-3.91	28.15	-0.14		3.76	35.76	0.11	
Regression-path	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	–	–			403.40	28.11			462.41	24.13		
N2Compatibility	–	–	–	–	-9.06	21.67	-0.42		5.65	23.87	0.24	
N1Typicality	–	–	–	–	-0.61	21.65	-0.03		-13.99	23.87	-0.59	
Interaction	–	–	–	–	22.56	43.29	0.52		19.83	47.75	0.42	
Second-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	298.11	56.33			435.87	78.20			555.18	78.75		
N2Compatibility	2.32	32.99	0.07		-12.49	40.64	-0.31		38.76	42.66	0.91	
N1Typicality	-61.19	54.21	-1.13		-14.49	40.64	-0.36		32.34	42.66	0.76	
Interaction	74.21	79.01	0.94		108.56	81.29	1.34		153.80	85.32	1.80	.07†
Regressions-out	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
(Intercept)	–	–			-1.86	0.21			-1.93	0.18		
N2Compatibility	–	–	–	–	-0.08	0.11	-0.72		-0.01	0.11	0.12	
N1Typicality	–	–	–	–	-0.15	0.12	-1.34		-0.05	0.11	-0.48	
Interaction	–	–	–	–	0.04	0.11	0.37		0.01	0.11	0.05	

† p < .1, * p < .05, ** p < .01, *** p < .001
Note: N2Compatibility stands for *N2-association Compatibility* and N1Typicality for *N1-association Typicality*; a hyphen (–) indicates data irrelevant for the sentence-final region.

There was a main effect of *N2-association Compatibility* for the first-pass reading times in the RC Subject region. As for the marginally significant interaction of the two factors for the second-pass reading times in the RC Verb region, the simple effect of *N1-association Typicality* was marginally significant in the *N2-association compatible* conditions ($\beta = 54.70$, $SE = 29.17$, $t = 1.88$, $p = .06$), indicating longer reading times in re-reading this region when the N1 was neutral than it was typical . The simple effect was not significant in the *N2-association incompatible* conditions.

Appendix I:
Post-hoc Norming Study (Experiment 2); Norming Study I (Experiment 3); Norming Study II (Experiment 3)

The following instructions were used for the questionnaires of the post-hoc norming study in Experiment 2 and the first and second norming studies (Norming Studies I and II) in Experiment 3.

これから、７６個の文を読んでいただき、個々の文が表現する事柄がどれだけ現実にあり得そうか、つまり典型的だと感じるかの度合い（典型度）を、「１」（全く典型的でない）～「５」（とても典型的である）の５段階で評定していただきます。

例えば、「バス運転手がバスを掃除している。」がとても典型的だと思ったら、

全く典型的でない　　とても典型的である
1　2　3　4　[5]

「５」を○で囲んでください。 また例えば、「バス運転手が飛行機を操縦している。」が全く典型的でないと思ったら、

全く典型的でない　　とても典型的である
[1]　2　3　4　5

「１」を○で囲んでください。

１～５の数字は、意図的にまんべんなく使うように配慮する必要はありません（同じ数字が特に多く使われてもかまいません)。あまり悩まずに、できるだけ素早く直感で判断していただければ結構です。

どうぞよろしくお願いします。

注意１：ページをめくったら、絶対に、前のページに戻らないでください。

注意２：一度回答したものは訂正しないでください。

注意３：判読できるような濃さで○を書いてください。

Item example:

１．警察が今まさに少年の性格を捜し回っている。

全く典型的でない　　とても典型的である
1　2　3　4　5

Appendix J
Target Stimuli in Experiment 3

Conditions (a), (b), (c), and (d) correspond to the *N2-association impossible + N1-association neutral*, *N2-association impossible + N1-association typical*, *N2-association possible + N1-association neutral*, and *N2-association possible + N1-association typical* conditions, respectively.

Item numbers	Conditions	Stimuli
1	a	警察が今まさに捜し回っている少年の性格がワイドショーで取り上げられた。
	b	警察が今まさに捜し回っている犯人の性格がワイドショーで取り上げられた。
	c	警察が今まさに注目している少年の性格がワイドショーで取り上げられた。
	d	警察が今まさに注目している犯人の性格がワイドショーで取り上げられた。
2	a	バスガイドがちょうど今引率している少年のスーツケースが風で倒れた。
	b	バスガイドがちょうど今引率しているツアー客のスーツケースが風で倒れた。
	c	バスガイドがちょうど今見張っている少年のスーツケースが風で倒れた。
	d	バスガイドがちょうど今見張っているツアー客のスーツケースが風で倒れた。
3	a	コーチが競技場で指導している少年のゼッケンが突風で吹き飛んだ。
	b	コーチが競技場で指導している陸上選手のゼッケンが突風で吹き飛んだ。
	c	コーチが競技場でながめている少年のゼッケンが突風で吹き飛んだ。
	d	コーチが競技場でながめている陸上選手のゼッケンが突風で吹き飛んだ。
4	a	塾講師が今まさに怒鳴りつけている少年の制服が雨で濡れている。
	b	塾講師が今まさに怒鳴りつけている男子学生の制服が雨で濡れている。
	c	塾講師が今まさに調べている少年の制服が雨で濡れている。
	d	塾講師が今まさに調べている男子学生の制服が雨で濡れている。
5	a	医師がたった今触診している少女の血液型が学会で議論されている。
	b	医師がたった今触診している患者の血液型が学会で議論されている。
	c	医師がたった今気にしている少女の血液型が学会で議論されている。
	d	医師がたった今気にしている患者の血液型が学会で議論されている。
6	a	芸能記者が玄関先で取材している少女の仕草がテレビに映っていた。
	b	芸能記者が玄関先で取材しているアイドルの仕草がテレビに映っていた。
	c	芸能記者が玄関先で見ている少女の仕草がテレビに映っていた。
	d	芸能記者が玄関先で見ているアイドルの仕草がテレビに映っていた。
7	a	教師がまさに今問い詰めている少女の携帯電話が教室に落ちていた。
	b	教師がまさに今問い詰めている女子高生の携帯電話が教室に落ちていた。
	c	教師がまさに今話題にしている少女の携帯電話が教室に落ちていた。
	d	教師がまさに今話題にしている女子高生の携帯電話が教室に落ちていた。
8	a	新聞記者がまさに今責め立てている少女の日記がインターネットで公開された。

	b	新聞記者がまさに今責め立てている大臣の日記がインターネットで公開された。
	c	新聞記者がまさに今探している少女の日記がインターネットで公開された。
	d	新聞記者がまさに今探している大臣の日記がインターネットで公開された。
9	a	作家が書斎で面談している男性の万年筆がテーブルから落ちた。
	b	作家が書斎で面談している編集者の万年筆がテーブルから落ちた。
	c	作家が書斎で見つめている男性の万年筆がテーブルから落ちた。
	d	作家が書斎で見つめている編集者の万年筆がテーブルから落ちた。
10	a	デザイナーが事務所で叱責している男性のパソコンが落雷で壊れた。
	b	デザイナーが事務所で叱責している助手のパソコンが落雷で壊れた。
	c	デザイナーが事務所で使っている男性のパソコンが落雷で壊れた。
	d	デザイナーが事務所で使っている助手のパソコンが落雷で壊れた。
11	a	強盗がちょうど今脅している男性のデスクが監視カメラでモニターされている。
	b	強盗がちょうど今脅している銀行員のデスクが監視カメラでモニターされている。
	c	強盗がちょうど今凝視している男性のデスクが監視カメラでモニターされている。
	d	強盗がちょうど今凝視している銀行員のデスクが監視カメラでモニターされている。
12	a	判事が法廷で諭している男性の眼鏡が証言台に置かれている。
	b	判事が法廷で諭している容疑者の眼鏡が証言台に置かれている。
	c	判事が法廷で指さしている男性の眼鏡が証言台に置かれている。
	d	判事が法廷で指さしている容疑者の眼鏡が証言台に置かれている。
13	a	機長がキャビンで捜している女性の髪型が機内で話題になっていた。
	b	機長がキャビンで捜している客室乗務員の髪型が機内で話題になっていた。
	c	機長がキャビンでほめている女性の髪型が機内で話題になっていた。
	d	機長がキャビンでほめている客室乗務員の髪型が機内で話題になっていた。
14	a	助産師が院内で呼び止めている女性の診察券が受付に届けられた。
	b	助産師が院内で呼び止めている妊婦の診察券が受付に届けられた。
	c	助産師が院内で探している女性の診察券が受付に届けられた。
	d	助産師が院内で探している妊婦の診察券が受付に届けられた。
15	a	消防士がまさに今救助している女性の指輪がベランダに落ちていた。
	b	消防士がまさに今救助している被災者の指輪がベランダに落ちていた。
	c	消防士がまさに今探し回っている女性の指輪がベランダに落ちていた。
	d	消防士がまさに今探し回っている被災者の指輪がベランダに落ちていた。
16	a	看護師がたった今手当てしている女性の松葉杖が床に落ちた。
	b	看護師がたった今手当てしている負傷者の松葉杖が床に落ちた。
	c	看護師がたった今運んでいる女性の松葉杖が床に落ちた。
	d	看護師がたった今運んでいる負傷者の松葉杖が床に落ちた。
17	a	運転手がちょうど今降ろそうとしている婦人の振る舞いが悪意に満ちていた。
	b	運転手がちょうど今降ろそうとしている乗客の振る舞いが悪意に満ちていた。
	c	運転手がちょうど今観察している婦人の振る舞いが悪意に満ちていた。
	d	運転手がちょうど今観察している乗客の振る舞いが悪意に満ちていた。

18	a	映画監督が現場で叱っている婦人の台本が机に積み上げられている。
	b	映画監督が現場で叱っている助監督の台本が机に積み上げられている。
	c	映画監督が現場で見ている婦人の台本が机に積み上げられている。
	d	映画監督が現場で見ている助監督の台本が机に積み上げられている。
19	a	ゴルファーがコースに連れ回している婦人の帽子がカートに置いてあった。
	b	ゴルファーがコースに連れ回しているキャディーの帽子がカートに置いてあった。
	c	ゴルファーがコースに残してきている婦人の帽子がカートに置いてあった。
	d	ゴルファーがコースに残してきているキャディーの帽子がカートに置いてあった。
20	a	部長が飲み屋で説教している婦人の経歴が社内でうわさになった。
	b	部長が飲み屋で説教している係長の経歴が社内でうわさになった。
	c	部長が飲み屋で酷評している婦人の経歴が社内でうわさになった。
	d	部長が飲み屋で酷評している係長の経歴が社内でうわさになった。
21	a	弁護士が今まさに事情聴取している紳士のスーツが泥で汚れている。
	b	弁護士が今まさに事情聴取している依頼人のスーツが泥で汚れている。
	c	弁護士が今まさに凝視している紳士のスーツが泥で汚れている。
	d	弁護士が今まさに凝視している依頼人のスーツが泥で汚れている。
22	a	カメラマンがスタジオで撮影している紳士の病気がニュースで明らかになった。
	b	カメラマンがスタジオで撮影しているモデルの病気がニュースで明らかになった。
	c	カメラマンがスタジオで心配している紳士の病気がニュースで明らかになった。
	d	カメラマンがスタジオで心配しているモデルの病気がニュースで明らかになった。
23	a	検察がたった今尋問している青年の手紙が英語に翻訳された。
	b	検察がたった今尋問している被告人の手紙が英語に翻訳された。
	c	検察がたった今調べている青年の手紙が英語に翻訳された。
	d	検察がたった今調べている被告人の手紙が英語に翻訳された。
24	a	保育士が園庭で呼びかけている青年の水筒がベンチに置かれている。
	b	保育士が園庭で呼びかけている園児の水筒がベンチに置かれている。
	c	保育士が園庭でながめている青年の水筒がベンチに置かれている。
	d	保育士が園庭でながめている園児の水筒がベンチに置かれている。

Appendix K
The Results of the First Three Regions (Experiment 3)

Table K-1 presents the means (and SEs) of the four measures in each of the first three regions in Experiment 3, and Table K-2 the results from the best-fit LME models.

Table K-1: The means (and SEs) of four eye-movement measures in the first three regions (Experiment 3)

Measures	RC Subject *police-NOM*	RC Adverb *right now*	RC Verb *searching for/ paying attention to*
First-pass (with regressions)			
N2-association incompatible + N1-association neutral	393 (37)	345 (18)	448 (30)
N2-association incompatible + N1-association typical	394 (33)	334 (18)	424 (24)
N2-association compatible + N1-association neutral	330 (31)	372 (28)	389 (25)
N2-association compatible + N1-association typical	401 (33)	355 (25)	376 (23)
Regression-path			
N2-association incompatible + N1-association neutral	–	466 (33)	535 (39)
N2-association incompatible + N1-association typical	–	450 (30)	522 (41)
N2-association compatible + N1-association neutral	–	479 (41)	456 (32)
N2-association compatible + N1-association typical	–	469 (41)	458 (33)
Second-pass			
N2-association incompatible + N1-association neutral	291 (53)	389 (59)	377 (54)
N2-association incompatible + N1-association typical	286 (54)	366 (50)	385 (54)
N2-association compatible + N1-association neutral	310 (52)	443 (65)	407 (53)
N2-association compatible + N1-association typical	354 (72)	479 (59)	420 (58)
Regressions-out			
N2-association incompatible + N1-association neutral	–	0.16 (0.03)	0.10 (0.02)
N2-association incompatible + N1-association typical	–	0.16 (0.04)	0.12 (0.04)
N2-association compatible + N1-association neutral	–	0.15 (0.03)	0.09 (0.03)
N2-association compatible + N1-association typical	–	0.17 (0.03)	0.11 (0.03)

Note: A hyphen (–) indicates data irrelevant for the sentence-initial region.

(continued)

Table K-2: The statistical results from the best-fit models for four eye-movement measures in the first three regions (Experiment 3)

Measures	RC Subject *police-NOM*				RC Adverb *right now*				RC Verb *searching for/ paying attention to*			
First-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	364.86	31.38			347.98	21.30			405.92	23.84		
N2Possibility	-21.69	23.87	-0.91		26.05	15.28	1.70	.09†	-56.39	22.81	-2.47	.017*
N1Typicality	-39.88	24.34	-1.64		11.48	15.29	0.75		21.03	16.35	-1.29	
Interaction	-74.47	48.06	-1.55		-1.29	30.60	-0.04		-14.09	32.68	-0.43	
Regression-path	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	–	–	–	–	459.85	35.50			489.15	33.65		
N2Possibility	–	–	–	–	14.22	29.74	0.48		-75.06	25.17	-2.98	.003**
N1Typicality	–	–	–	–	8.88	28.51	0.31		6.23	25.18	0.25	
Interaction	–	–	–	–	-14.40	55.64	-0.26		-20.51	50.33	-0.41	
Second-pass	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
(Intercept)	310.40	57.66			419.19	61.18			397.38	52.09		
N2Possibility	43.18	30.00	1.44		83.68	31.66	2.64	.008**	32.89	45.40	0.72	
N1Typicality	-19.64	30.00	-0.65		-6.83	31.66	-0.22		-10.18	31.65	-0.32	
Interaction	-49.73	60.01	-0.83		-59.69	63.32	-0.94		-5.88	63.31	-0.09	
Regressions-out	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*	*β*	*SE*	*z*	*p*
(Intercept)	–	–	–	–	-1.86	0.19			-2.66	0.29		
N2Possibility	–	–	–	–	-0.01	0.11	-0.13		-0.06	0.14	-0.46	
N1Typicality	–	–	–	–	-0.06	0.11	-0.53		-0.01	0.23	-0.05	
Interaction	–	–	–	–	-0.04	0.11	-0.35		-0.01	0.14	-0.07	

† p < .1, * p < .05, ** p < .01, *** p < .001
Note: N2Possibility stands for *N2-association Possibility* and N1Typicality for *N1-association Typicality*; a hyphen (–) indicates data irrelevant for the sentence-final region.

For the RC Adverb region, there was a main effect of *N2-association Possibility* for the second-pass times, indicating that the participants took longer to re-read this region in the *N2-association possible* conditions compared to the *N2-association impossible* conditions. As for the RC Verb region, there were main effects of *N2-association Possibility* for the first-pass and regression-path times. Note that in the RC Verb region, different lexical items were used between *N2-association impossible* conditions on the one hand and *N2-association possible* conditions on the other.

Appendix L
Stimuli in Experiment 4

Conditions (a), (b), (c), and (d) correspond to the *experimental sentence + word related to the N1 association*, *experimental sentence + word non-related to the N1 association*, *baseline sentence + word related to the N1 association*, and *baseline sentence + word non-related to the N1 association* conditions, respectively.

Item numbers	Conditions	Sentence	Word
1	a	犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。	死亡
	b	犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。	地球
	c	機内でスチュワーデスが乗客にビールをかけられた。	死亡
	d	機内でスチュワーデスが乗客にビールをかけられた。	地球
2	a	警察官が慎重に調べた女性の手袋がほこりで汚れていた。	連行
	b	警察官が慎重に調べた女性の手袋がほこりで汚れていた。	半減
	c	誕生日に親が娘にプレゼントをせびられた。	連行
	d	誕生日に親が娘にプレゼントをせびられた。	半減
3	a	赤ちゃんがしつこく叩いた少年の帽子が床に置かれていた。	反撃
	b	赤ちゃんがしつこく叩いた少年の帽子が床に置かれていた。	元旦
	c	喫茶店でウェイトレスがお客にアイスコーヒーを運んだ。	反撃
	d	喫茶店でウェイトレスがお客にアイスコーヒーを運んだ。	元旦
4	a	検察官が何とか見つけ出した遺族の手紙がテレビで公表された。	保護
	b	検察官が何とか見つけ出した遺族の手紙がテレビで公表された。	文化
	c	入り口で店員がお客さんにチラシを配った。	保護
	d	入り口で店員がお客さんにチラシを配った。	文化
5	a	カメラマンが何枚も撮影した婦人の豪邸が意外に小さかった。	仕草
	b	カメラマンが何枚も撮影した婦人の豪邸が意外に小さかった。	雨滴
	c	年度末に部長が部下に評価書を破かれた。	仕草
	d	年度末に部長が部下に評価書を破かれた。	雨滴
6	a	彼女がいたずらをした男子学生のパソコンが広告に載っていた。	青春
	b	彼女がいたずらをした男子学生のパソコンが広告に載っていた。	駐日
	c	動物園で観光客がサルにバナナを取られた。	青春
	d	動物園で観光客がサルにバナナを取られた。	駐日
7	a	子どもたちがいっせいに注目した博物館の学芸員が椅子に座っていた。	点灯
	b	子どもたちがいっせいに注目した博物館の学芸員が椅子に座っていた。	食材
	c	郵便局で親が息子に手紙を送った。	点灯
	d	郵便局で親が息子に手紙を送った。	食材
8	a	大男が火炎瓶を投げつけたホテルの支配人がとても長身だった。	延焼

	b	大男が火炎瓶を投げつけたホテルの支配人がとても長身だった。	湾内
	c	保育園で保育士が赤ちゃんにおもちゃを与えた。	延焼
	d	保育園で保育士が赤ちゃんにおもちゃを与えた。	湾内
9	a	保護者がひどく非難した学習塾の講師が控室で準備していた。	閉校
	b	保護者がひどく非難した学習塾の講師が控室で準備していた。	重厚
	c	展覧会でアーティストがゲストにパンフレットを返された。	閉校
	d	展覧会でアーティストがゲストにパンフレットを返された。	重厚
10	a	新聞記者がしつこく電話した市役所の設計者がラジオに出演していた。	混線
	b	新聞記者がしつこく電話した市役所の設計者がラジオに出演していた。	例証
	c	昨年末に新入社員が上司にお歳暮を贈った。	混線
	d	昨年末に新入社員が上司にお歳暮を贈った。	例証
11	a	芸能人が大いに絶賛した豪華客船の客室乗務員がデッキでつまずいた。	高騰
	b	芸能人が大いに絶賛した豪華客船の客室乗務員がデッキでつまずいた。	改定
	c	節分に子供が先生に豆を投げた。	高騰
	d	節分に子供が先生に豆を投げた。	改定
12	a	イノシシが勢いよく体当たりした観光バスのツアー客がたいそう美人だった。	修理
	b	イノシシが勢いよく体当たりした観光バスのツアー客がたいそう美人だった。	模索
	c	謝恩会で卒業生が恩師に花束を捨てられた。	修理
	d	謝恩会で卒業生が恩師に花束を捨てられた。	模索

The following is filler sentences (the asterisk indicates that the word in question is a non-real word). These fillers were also used in Experiments 2 and 3.

Item numbers	Sentence	Word
1	その研究者はビデオゲームが及ぼす害について研究していたが全く結果が出なかった。	工事
2	看護師が今すぐに知りたいのは患者がその日何を食べたかという情報だ。	中毒
3	社長が女性と三つ星レストランへ行ったがまるで口に合わなかった。	接待
4	県警はどこの組織がからんでいたか速やかに探り出して書類を提出した。	花壇
5	その科学者はどこへ行くにも助手に指示されて大きなカバンを持ち歩いていた。	機械
6	その浪人生は友人に言われて参考書を肌身離さず持っていた。	受験
7	大臣はある重要書類を秘書に貸し出したが間違ったものを渡してしまい焦っていた。	電源
8	先日カップルが友人に招待状を無くされたことがなぜか新聞に載った。	結婚
9	ある生徒が生徒会長が学校を休んでマンガ本を立ち読みしていたと教頭に告げ口した。	欠席
10	記者達は警視庁があの晩に誰がその家に居たのかまだ公表していないことを批判した。	大安
11	高校生が地方からアイドルに会いに来たが終始しゃべることができなかった。	握手
12	不思議なことに無口な新人社員が社長に提案されて株で大儲けをしている。	書籍
13	消防隊員はかつて国語教師だったが校長に推薦されて消防隊に入った。	*岩抽

14 校庭で先生が生徒にフリスビーをすごいスピードで当てられた。 *吸飼
15 大統領が報道官にスピーチの原稿を急いで作るように命じた。 *筋宅
16 困ったことにその探偵は手帳を忘れてしまった。 *鎖残
17 男の子がニューモデルのバイクをじっと見つめているのを店長が見ていた。 *握暦
18 過酷な演出に女優が怒って事務所の社長を呼びつけた。 *稿曇
19 派手なロックスターを小学生達が大声でからかった。 *排低
20 司会者がお気に入りの解答者に解答をさりげなく視線で示した。 *墓透
21 その老婆は昨日デパートで何を買ったのか思い出せないと救急隊に伝えた。 *富首
22 イベントで訪問者にスタッフが記念品を渡したことがテレビで紹介された。 *悲累
23 おばあちゃんがテーブルに団子があると言ったが甥は探すことができなかった。 *悪戻
24 店長が突然泣き出したので店員が何事かと思い救急車を呼んでしまった。 *庫商
25 おしゃれなバーで白いネクタイの実業家が OL に話しかけた。 *灰請
26 著名な物理学者の講演の後に珍しく聴衆がスタンディングオベーションをした。 *離紳
27 娘の誕生日に大富豪が自宅のワインの貯蔵室からとっておきの一本を選んだ。 *翼唇
28 その探偵はある政治家が誰と付き合っているかひそかに調査している。 *亜臨
29 そのスポーツキャスターは今場所横綱が全勝したと報じた。 *嵐老
30 刑事は老夫婦が殺される直前に誰と会ったかすぐさま突き止めた。 *芝純
31 パソコン修理で技師がやって来たので用務員がお茶を運んだ。 *旅森
32 アイスが溶けてしまったので、子どもがおじいちゃんに小遣いをもらった。 *卵真
33 演説をしたのは青年だったが演説の原稿を作ったのは恋人だった。 *酪浸
34 プロレスラーが観客にパイプ椅子を持ってリングに上がるように命令した。 *曜津
35 ある集中講義の中で大学生が教授が月が四角いと言ったことに驚いた。 *擁信
36 社員が係長に来月何が何でも成績を上げることを約束した。 *肝然
37 労働者が雇用主が怠惰だと批判したことが世間に露呈してしまった。 *狩胞
38 息子が母親に英会話教室に通いたいとお願いをしたが却下された。 *遊詳
39 娘が道を間違えないように父親がとても詳細な地図を事前に用意した。 *玄賠
40 裁判員たちは有名な牧師が信者をいじめたという見解で一致した。 *桁伴
41 長い列に並んで待っていたが結局紳士は総理大臣に会えなかった。 *襲綿
42 タクシー運転手が詐欺をしたのは周知の事実だが乗客は決して信じなかった。 *妙却
43 学校の決定に女子児童は喜んだが男子児童は不平を言った。 *繰府
44 常連客がクロークにいかにも上品そうなコートをこれみよがしに預けた。 *翌蔵
45 学者は絶滅危惧種の生物を発見したと思ったが上司に否定された。 *巡融
46 ショップ店員が丁寧にも客に品物を店先まで運んであげた。 *枕粛
47 清掃員に上司が夕飯を買いに行かせたことが公になり問題となった。 *爽幻
48 子どもが親を手伝うのは彼は当然のことだと思っていた。 *肥承

Appendix M
Norming Study I (Experiment 4)

What follows is the instructions used for the questionnaire in the first norming study (Norming Study I) in Experiment 4.

この度は、調査へのご協力ありがとうございます。
これはあなたの言語能力を測るものではありません。調査で得られた個人情報は厳密に扱い、また結果を公表する際には匿名で行うなど、あなたのプライバシーを侵害することは一切ありません。

課題：
文を読んで、その内容がどの程度妥当か（現実に起こり得るか）を５段階で判定してください。
（現実に起こり得る）　５　　４　　３　　２　　１　（現実に起こり得ない）
例：　「犬がドックフードを食べた」　＝　「５」
　　「犬が新幹線を運転した」　＝　「１」

手順：
１．文が呈示されたら黙読をしてください。時間をかけても構いませんが、正確に読んでください。
２．読み終えたら、５～１の尺度で、文の内容がどの程度現実に起こり得るかを判定してください。一つの選択肢を選んで、「次へ」をクリックしてください。
（以下、１と２の繰り返しです）

注意：
回答中、絶対に「戻る」ボタンは押さないでください。エラーが起きてしまいます（データが正常に取れなくなってしまいます）。
（誤って「戻る」をクリックしてしまった場合は、戻った画面の「次へ」をすぐにクリックし、回答を続けてください）

文は全部で 72 個あります。（15 分程度で終わります）
最後の文の質問に回答し終えたら、「送信」をクリックしてください。
「回答を記録しました」と出たら、正常に終わったことになります。

Item example:

犯人が鈍器で男性を攻撃した。

どの程度現実に起こり得るかを５段階で判定してください。
5
4
3
2
1

Appendix N

Norming Study II (Experiment 4); Norming Study III (Experiment 4); Norming Study I (Experiment 5); Norming Study II (Experiment 5)

The following is the instructions in the questionnaire used for the second and third norming studies (Norming Studies II and III) in Experiment 4 and the first and second norming studies (Norming Studies I and II) in Experiment 5.

この度は、調査へのご協力ありがとうございます。
これはあなたの言語能力を測るものではありません。調査で得られた個人情報は厳密に扱い、また結果を公表する際には匿名で行うなど、あなたのプライバシーを侵害することは一切ありません。

課題：
文を読んで、その結果を想像した上で、指定される単語がどの程度連想しやすいかを５段階で、できる限り素早く判定してください。
（とても連想しやすい）　５　　４　　３　　２　　１　（とても連想しにくい）
例：　「誰かが水を冷凍庫に入れた」
　　→　「氷」　＝　「５」
　　「誰かが水を熱した」
　　→　「氷」　＝　「１」

手順：
１．文が呈示されたら黙読をしてください。時間をかけても構いませんが、正確に読んでください。
２．読み終えたら、５～１の尺度で、指定された単語がどの程度連想しやすいかを、できる限り素早く判定してください。一つの選択肢を選んで、「次へ」をクリックしてください。
（以下、１と２の繰り返しです）

注意：
回答中、絶対に「戻る」ボタンは押さないでください。エラーが起きてしまいます（データが正常に取れなくなってしまいます）。
（誤って「戻る」をクリックしてしまった場合は、戻った画面の「次へ」をすぐにクリックし、回答を続けてください）
また、できる限り静かな場所で、集中して作業を行ってください。

文は全部で 150 個あります。
最後の文の質問に回答し終えたら、「送信」をクリックしてください。
「回答を記録しました」と出たら、正常に終わったことになります。

Item example:

犯人が鈍器で男性を攻撃した。

「死亡」が、文の内容を想像した上で、どの程度連想しやすいかを５段階で判定してください。
5
4
3
2
1

Appendix O
Stimuli in Experiment 5

Conditions (a), (b), (c), and (d) correspond to the *experimental sentence + word related to the N2 association*, *experimental sentence + word non-related to the N2 association*, *baseline sentence + word related to the N2 association*, and *baseline sentence + word non-related to the N2 association* conditions, respectively.

Item numbers	Conditions	Sentence	Word
1	a	犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。	破壊
	b	犯人が鈍器で攻撃した男性の外車が防犯カメラに映っていた。	当初
	c	機内でスチュワーデスが乗客にビールをかけられた。	破壊
	d	機内でスチュワーデスが乗客にビールをかけられた。	当初
2	a	警察官が慎重に調べた女性の手袋がほこりで汚れていた。	押収
	b	警察官が慎重に調べた女性の手袋がほこりで汚れていた。	流行
	c	誕生日に親が娘にプレゼントをせびられた。	押収
	d	誕生日に親が娘にプレゼントをせびられた。	流行
3	a	赤ちゃんがしつこく叩いた少年の帽子が床に置かれていた。	変形
	b	赤ちゃんがしつこく叩いた少年の帽子が床に置かれていた。	新卒
	c	喫茶店でウェイトレスがお客にアイスコーヒーを運んだ。	変形
	d	喫茶店でウェイトレスがお客にアイスコーヒーを運んだ。	新卒
4	a	検察官が何とか見つけ出した遺族の手紙がテレビで公表された。	保管
	b	検察官が何とか見つけ出した遺族の手紙がテレビで公表された。	既存
	c	入り口で店員がお客さんにチラシを配った。	保管
	d	入り口で店員がお客さんにチラシを配った。	既存
5	a	カメラマンが何枚も撮影した婦人の豪邸が意外に小さかった。	名所
	b	カメラマンが何枚も撮影した婦人の豪邸が意外に小さかった。	辞典
	c	年度末に部長が部下に評価書を破かれた。	名所
	d	年度末に部長が部下に評価書を破かれた。	辞典
6	a	彼女がいたずらをした男子学生のパソコンが広告に載っていた。	故障
	b	彼女がいたずらをした男子学生のパソコンが広告に載っていた。	無職
	c	動物園で観光客がサルにバナナを取られた。	故障
	d	動物園で観光客がサルにバナナを取られた。	無職
7	a	子どもたちがいっせいに注目した博物館の学芸員が椅子に座っていた。	緊張
	b	子どもたちがいっせいに注目した博物館の学芸員が椅子に座っていた。	調達
	c	郵便局で親が息子に手紙を送った。	緊張
	d	郵便局で親が息子に手紙を送った。	調達
8	a	大男が火炎瓶を投げつけたホテルの支配人がとても長身だった。	重体

	b	大男が火炎瓶を投げつけたホテルの支配人がとても長身だった。	農場
	c	保育園で保育士が赤ちゃんにおもちゃを与えた。	重体
	d	保育園で保育士が赤ちゃんにおもちゃを与えた。	農場
9	a	保護者がひどく非難した学習塾の講師が控室で準備していた。	退職
	b	保護者がひどく非難した学習塾の講師が控室で準備していた。	交通
	c	展覧会でアーティストがゲストにパンフレットを返された。	退職
	d	展覧会でアーティストがゲストにパンフレットを返された。	交通
10	a	新聞記者がしつこく電話した市役所の設計者がラジオに出演していた。	逃亡
	b	新聞記者がしつこく電話した市役所の設計者がラジオに出演していた。	山岳
	c	昨年末に新入社員が上司にお歳暮を贈った。	逃亡
	d	昨年末に新入社員が上司にお歳暮を贈った。	山岳
11	a	芸能人が大いに絶賛した豪華客船の客室乗務員がデッキでつまずいた。	昇給
	b	芸能人が大いに絶賛した豪華客船の客室乗務員がデッキでつまずいた。	冷害
	c	節分に子供が先生に豆を投げた。	昇給
	d	節分に子供が先生に豆を投げた。	冷害
12	a	イノシシが勢いよく体当たりした観光バスのツアー客がたいそう美人だった。	手術
	b	イノシシが勢いよく体当たりした観光バスのツアー客がたいそう美人だった。	長期
	c	謝恩会で卒業生が恩師に花束を捨てられた。	手術
	d	謝恩会で卒業生が恩師に花束を捨てられた。	長期

The filler sentences were the same as those used in Experiment 4 (see Appendix L).