Relative clause processing in Brazilian Portuguese and Japanese

by

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Abstract

This dissertation considers ambiguity resolution in regard to two issues. First, it investigates factors that lead the human parser to favour some types of interpretations over others when faced with some types of ambiguous input. Second it examines the reanalysis process that takes place when initial biases lead to incorrect interpretations.

The first part of the dissertation (Chapter 1) proposes that reanalysis is a process that requires the maximal satisfaction of constraints (similar to first pass parsing as in Gibson & Pearlmutter, 1998; MacDonald, Pearlmutter & Seidenberg, 1994) rather than the minimization of the number of operations involved as has been suggested previously (Frazier, 1994; Fodor & A. Inoue, 1994). Three experiments in Japanese using main/embedded clause ambiguities are reported in support of this claim.

The second part of the dissertation (Chapters 2, 3 and 4) uses a well-established generalization as a starting point, namely, that a modifying phrase is preferentially attached to the closest available site. A recent question in the literature has been to determine ways of parameterizing this principle in order to account for cross-linguistic variations observed in the attachment of relative clauses (Cuetos & Mitchell, 1988). In Chapter 2, the potential parametrizations that may explain the phenomenon at hand are restricted based on data from Brazilian Portuguese. In Chapter 3, an experiment in Japanese investigates the locality preference in this head-final language. Finally, in Chapter 4, it will be suggested that ambiguities in relative clause attachment are not only well-suited to investigate cross-linguistic phenomena but also various properties of the human parser that lie beyond the realm of grammatical well-formedness, and two on-going projects are briefly described.

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Contents

List of Figures

List of Tables

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Introduction

This dissertation considers ambiguity resolution in regard to two issues. First, it investigates factors that lead the human parser to favour some types of interpretations over others when faced with an ambiguous input. Second it examines the reanalysis process that takes place when initial biases lead to incorrect interpretations. These two basic questions will allow for language processing to be investigated in its universal aspects as well as in its distinct manifestations in various languages. More specifically, it will be assumed that the parsing mechanism responsible for human language processing is the same across all languages and that any apparent differences are due to the interaction between such a cognitive mechanism and specific aspects of the languages being considered. Thus the characterization of the human parser requires not only positing principles that can account for its similar behaviour in distinct languages but also determining the extent to which such principles are amenable to parameterization in order to account for instances in which the parser behaves differently when processing some types of languages.

Although the distinction between parsing algorithm and grammar may not necessarily be encoded at the neurological level as suggested by some models (e.g., Elman, 1991), nevertheless, at a more abstract level of representation (Marr, 1982) such dichotomy is useful to pose questions about human language processing. Given the constraints that are known to apply in the well-formedness of sentences belonging to a language, one may ask how it is that such grammatical constraints manifest themselves in the processing of sentences by native speakers. But more crucial here is what happens in cases where the grammar does not impose any constraints. Exactly in those cases where sentence well-formedness does not dictate the interpretation to be followed, the cognitive processes underlying language

processing may reveal themselves. By observing such cases, psycholinguists have proposed a number of traits that characterize the human parser independent of language. The first part of this dissertation argues against one such characterization and proposes replacing it based on data from Japanese. The second part, on the other hand, considers ways of parameterizing another principle in order to account for cross-linguistic differences reported in the literature.

The first part of the dissertation (Chapter 1) is primarily concerned in determining a general principle in reanalysis which equally applies across a number of distinct languages. In particular, it will be proposed that reanalysis is a process that requires the maximal satisfaction of constraints rather than the minimization of the number of operations involved as has been suggested previously.

The second part of the dissertation (Chapters 2, 3 and 4) uses a well-established generalization as a starting point, namely, that a modifying phrase is preferentially attached to the closest available site. A recent question in the literature has been to determine ways of parameterizing this principle in order to account for cross-linguistic variations observed in the attachment of relative clauses. In Chapter 2, the potential parametrizations that may explain the phenomenon at hand are restricted based on data from Brazilian Portuguese. In Chapter 3, an experiment in Japanese investigates the locality preference in this head-final language. Finally, in Chapter 4, it will be suggested that ambiguities in relative clause attachment are particularly well-suited to investigate properties of the parser that lie beyond the realm of grammatical well-formedness.

The following discusses some of the issues to be addressed in the two parts of the dissertation as well the basic assumptions being made.

Initial assumptions

It will be assumed that the human parser processes sentences incrementally by integrating each incoming word without delay to the mental representation of the sentence (e.g., Marslen-Wilson & Tyler, 1980, 1981). The mental representation being constructed is a set of one or more syntactic tree structures, in which there is a one-to-one correspondence between trees

and interpretations. Hence, the expressions *tree structure* and *interpretation* of a sentence are often going to be used interchangeably. Integrating a new word into the mental representation entails updating its tree structures by attaching the word to each tree. It will not be crucial in the discussion whether the mental representation actually holds exactly one interpretation as in a serial model in which only one interpretation is pursued at a time (Frazier & Fodor, 1978; Gorrell, 1995; Pritchett, 1992), or more than one interpretation as in a ranked parallel model where various interpretations are constructed simultaneously and ranked according to some metric which also yields a threshold indicating the most favoured interpretations (Gibson, 1991; Gorrell, 1989).

Incremental parsing requires local decision-making in that the parser has to attach each incoming word solely based on the mental representation built so far without the benefit of knowing the words that are coming next. This assumption is not totally accurate as a few characters upstream may actually be viewed parafoveally and used for word identification (Rayner, Sereno, Morris, Schmauder & Clifton, 1989), thus affecting some attachment decisions. Crucially, however, such look-ahead ability is restricted and it will be assumed that it does not fundamentally affect the claims being made here.

If an attachment decision is contradicted by ensuing words (the *disambiguating segment* of the sentence, which indicates the actual interpretation intended), the parser has to reanalyse in order to correct the mental representation. *Reanalysis* will refer to the process of changing the mental representation so as to make it conform with the disambiguating segment of the input sentence. In a serial processing model, reanalysis involves changing the single tree structure in order to create a new interpretation (e.g., Frazier, 1994). In ranked parallel models, it requires reactivating tree structures which have fallen below a certain threshold (Gibson, Babyonyshev & Kaan, 1998). First-pass processing will refer to parsing when reanalysis is not taking place.

Lazy and greedy parsing

Although Chapter 1 only examines the reanalysis stage of sentence processing, the discussion can be couched in more general terms as the following suggests. Modular approaches to

sentence processing have often explained native speakers' preference for simple over complex syntactic structures through some type of minimal effort strategy in which the human parser opts for the interpretation whose corresponding tree structure requires least effort to be built. In this context, effort or complexity has been measured, for example, in terms of the number of nodes necessary to build the tree structure (*minimal attachment* (Frazier, 1987); *simplicity* (Gorrell, 1995)). This type of model will be referred to as *lazy parsing* as it rests on the assumption that the parser's primary constraint is to do as little work as possible in relation to some metric.

Alternatively, because simpler structures tend to satisfy subcategorization requirements earlier in the sentence, the preference for simpler structures can also be explained by resorting to the idea that the human parser attempts to maximally satisfy subcategorization-related constraints as soon as possible (Pritchett, 1992; Gibson, 1991, 1998). This second approach will be called *greedy parsing* as it assumes that the parser tries to maximally satisfy processing constraints immediately at each point in the sentence.

In first-pass processing, lazy versus greedy parsing have been addressed only indirectly as each one of them has been associated for the most part with modular and non-modular models of parsing respectively. Although the experimental results disfavour modular proposals in which only structural biases were assumed to guide the initial parsing preferences (e.g., Trueswell, Tanenhaus & Garnsey, 1994; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995), these results do not necessarily rule out versions of lazy parsing in which the human parser attempts to minimize all types of operations and not just tree building.

In reanalysis, in particular, a number of proposals have been based on some type of minimal effort strategy according to which the parser attempts to make the least number of necessary changes on the mental representation in order to obtain interpretations compatible with the disambiguating region of the sentence (A. Inoue & Fodor, 1995; Frazier, 1994; Mazuka & Itoh, 1995). This kind of proposal is particularly well-suited for serial parsing models in which only one interpretation is pursued at a time and hence reanalysis can be characterized as the process of making incremental changes on the tree structure until a well-formed representation is obtained. Thus an interpretation that requires an extra change beyond the minimum necessary to obtain a well-formed representation will be disfavoured

even if it allows for more constraints to be satisfied. This is in contrast with greedy parsing according to which the parser prefers to satisfy more constraints even if that requires more changes to be performed.

In Chapter 1, two strategies that may be adopted by the parser during reanalysis are compared. The two strategies, *minimal change* and *maximal grammaticality*, are instances of lazy and greedy parsing respectively and will allow for these two frameworks to be discussed within the reanalysis process. It will be argued that informal judgements and empirical results used in the literature in favour of minimal change are often ambiguous and can also be explained by a maximal grammaticality principle. The chapter then proceeds to investigate how the parser uses subcategorization information during reanalysis. The discussion moves away from the types of information sources used in parsing and concentrates instead on how one single type of information is being used. The conclusion will be that the series of three Japanese experiments presented is best explained by maximal grammaticality and hence within a greedy parsing framework.

Modifier attachment

While the first part of the dissertation proposes that a previous parsing principle should be replaced in face of data from Japanese, the second part looks into ways of defending the validity of a generalization that has been challenged in the last ten years based on empirical results from a number of languages.

The generalization in question has stemmed from the observation that whenever the attachment of a phrase is equally possible to more than one site as far as factors such as grammaticality and plausibility are concerned, such a phrase is preferentially attached to the closest site. This phenomenon is observable with various types of modifying phrases in a number of languages as the following sample suggests.

Example (1)

Temporals.

a. I ate the ice-cream that I bought *yesterday.*

b. *Kinou* katta aisu-kurimu-o tabeta. (Japanese)

Instrumentals.

c. The policeman saw the man who was looking at the woman *with binoculars.*

d. Policajt viděl muže který koukal na ženu *s dalekohledem.* (Czech)

Locatives.

e. The daughter of the professor *in Sudan* likes apples.

f. Die Tochter des Professors *in Sudan* mag Äpfel. (German)

Coordinations.

g. John bought a laptop computer with a TFT screen *and a fax machine.*

h. João comprou um laptop com monitor TFT e *um fax.* (Portuguese)

Each pair of sentences in Example (1) presents a sentence in English and its translation into the language indicated between parentheses. In all sentences, the phrase in italics can modify (or be coordinated with) either of the underlined sites, but in each case the preference is to minimize the distance between the modifying phrase and the modified head. For example, in the Japanese Example (1b), **kinou** ("yesterday") can refer to **katta** ("bought") or **tabeta** ("ate"), but the preference is to attach the adverb to the closest verb **katta**. This preference to attach locally has been proposed within various frameworks and justified accordingly in a number of different ways (Frazier, 1987; Gibson, 1998; Kimball, 1973; Phillips, 1995).

However, in the last ten years, the universality of such local attachment preference or *locality* for short (following Gibson, 1998) has been challenged by a growing body of empirical results. The initial observation is due to Cuetos & Mitchell (1988) who reported results on the following construction in English and Spanish.

Example (2)

a. Someone shot the servant of the actress [$_{RC}$ *who was on the balcony*].

b. Alguien disparó contra el criado de la actriz [$_{RC}$ *que estaba en el balcón*].

As predicted by locality, native English speakers showed a preference to attach the relative clause (RC) in Example (2a) to the closest head noun (**actress**). In the equivalent construction in Spanish (Example (2b)) however, native speakers preferred to attach the RC to the high noun (**criado**), in other words to the highest noun available for attachment in the tree structure. The non-local attachment preference observed in Spanish has also been

empirically observed in a number of other languages (Dutch (Brysbaert & Mitchell, 1996); French (Zagar, Pynte & Rativeau, 1997); German (Hemforth, Konieczny & Scheepers, in press); results in Italian indicate an off-line preference for the high site as well (de Vincenzi & Job, 1995)).

Despite the evidence against locality, researchers have for the most assumed, as will be in this dissertation, that locality should be maintained as a universal constraint in the parser and that some type of parametrization should be proposed in order to explain the cross-linguistic variation observed (but see the *tuning hypothesis* in Cuetos, Mitchell & Corley, 1996). Two types of arguments can be used to support locality. First, all the local attachment preferences observed in various ambiguous constructions across languages, of which Example (1) is just a sample, would have to be deemed coincidental and be motivated case by case if no such tendency is inherent to the parser (see also Gibson, 1998, for locality effects in unambiguous constructions). Second, the high attachment preference observed in Example (2b) is likely to be a unique counter-example to the locality claim rather than one of many such instances. Indeed, minimal variations of the construction in Example (2b) have systematically shown to revert the preference to low attachment (in other words, attachment to the site located low in relation to the other candidate sites in the tree structure). The following describes three of such variations of the above construction that have been tested in the literature.

When the preposition **of** is replaced by a preposition with semantic content such as **with** (Example (3)), attachment of the RC favours the local noun in English but more interestingly also in Spanish (Gilboy, Sopena, Clifton & Frazier, 1995).

Example (3)
a. The count ordered the steak with the sauce [$_{RC}$ that the chef prepares especially well].
b. El donce pidió el bistec con la salsa [$_{RC}$ que el cocinero preparaba especialmente bien].

Moreover, in constructions with three rather than two candidate nouns, the RC attachment in Spanish again reverts to the closest noun (Gibson, Pearlmutter & Torrens, in press; see also Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996, for similar results for both English and Spanish).

Example (4) (Adapted from Gibson, Pearlmutter & Torrens, in press.)
Un alumno insultó a las secretarias de los professores de las clases [$_{RC}$que no gustaron a los estudiantes].

"A pupil insulted the secretaries of the professors of the classes that were not fancied by the students."

In the above example, Spanish speakers prefer to attach the RC to the low noun **clases**, their second choice for attachment is the high noun **secretarias**, whereas the middle noun **professores** is the least preferred site for attachment.

A third example of a construction similar to Example (2b) that does not present a high attachment preference comes from German (Hemforth, Konieczny & Scheepers, in press).

Example (5)

a. Die Tochter der Lehrerin, [$_{RC}$die aus Deutschland kam], traf John.
the daughter the$_{Gen}$ teacher who from Germany came met John

"The daughter of the teacher who came from Germany met John."

b. Die Tochter der Lehrerin [$_{PP}$aus Deutschland] traf John.
the daughter the$_{Gen}$ teacher from Germany met John

"The daughter of the teacher from Germany met John."

Although native speakers of German prefer to attach the RC in Example (4a) to the high noun **daughter**, a PP with an equivalent meaning in Example (4b) is preferentially attached to the low noun **teacher**.

Findings like the three examples above suggest that the high attachment preference encountered in Example (2b) is likely to be unique and therefore maintaining locality as an inherent property of the human parser is a reasonable course to take. More than that, the uniqueness of this construction can be used to explore rather interesting cross-linguistic aspects of language processing. Here is a trait for which there is considerable independent evidence, and nevertheless it fails to manifest itself in one specific construction in a number of languages. From this point of view, this is a prime phenomenon for looking into ways that an inherent property of the human parser interacts with idiosyncratic features of various languages to yield apparently contradicting parsing patterns.

Researchers have indeed taken advantage of this phenomenon and in the last ten years

a number of studies has investigated various aspects of the construction. This has led to the emergence of a truly cross-linguistic enterprise, although still mostly restricted to West-European languages. The various proposals advanced in the literature have allowed distinct factors to be investigated and their role in parsing to be better understood. The one obvious conclusion is that more data are needed from various types of languages. This part of the dissertation is one step in this direction as it provides data from Japanese and Brazilian Portuguese to the on-going discussion. The analysis of these experimental results not only provides insight into the RC attachment phenomenon at hand, but it also raises a number of issues regarding general properties of the human parser. In cases where the grammar does not require an RC to be attached to a specific site, the parser is likely to present its underlying nature. Uncovering such biases will not always be directly relevant to the parametrization necessary to explain the cross-linguistic difference observed by Cuetos and Mitchell, but it allows unexpected traits of the human parser to be revealed.

Chapter 2 is the most directly concerned with the cross-linguistic phenomenon and proposes to narrow down the possible factors responsible for the RC attachment difference across languages by providing evidence from Brazilian Portuguese. Chapter 3 examines how predicted categories are used by the parser in order to build a structure which allows for words processed so far to be attached in Japanese. Chapter 4 proposes two ways in which RC attachment ambiguities can be explored in order to investigate properties of the parsing algorithm.

Chapter 1

Reanalysis in Japanese multi-clausal sentences

1.1 Introduction

The early influence of non-structural factors in first-pass parsing (e.g., Trueswell, Tanenhaus & Garnsey, 1994; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995) has been used to argue against modular approaches to parsing and in particular against models which predict that the parser's initial preferences are guided by its attempt to minimize structural complexity (Frazier & Fodor, 1978; Gorrell, 1995). However, the question remains as to whether a minimal effort strategy is nevertheless used at the reanalysis stage as the parser may attempt to minimally change the mental representation to make it conform with the disambiguating region of the sentence (Frazier, 1994; Fodor & A. Inoue, 1994). The first experiment in this chapter suggests that the amount of change performed correlates with difficulty during reanalysis, hence, providing a potential motivation for the parser to minimize change. Still, the following two experiments indicate that such effort minimization has no impact on the interpretations favoured by the parser during reanalysis. Instead, even when reanalysing, the parser is constraint-driven in that it makes changes in the mental representation as long as requirements can be satisfied.

As the human parser processes a sentence incrementally, integrating words without de-

lay to a mental representation (a mental representation is assumed to be a set of one or more syntactic tree structures, where each tree corresponds to exactly one interpretation of the input sentence), such local decision-making may be contradicted by ensuing words, namely, the *disambiguating segment* of the sentence. When such discrepancies are detected, the parser has to reanalyse in order to correct the mental representation. *Reanalysis* will refer to the process of changing the mental representation so as to make it conform with the disambiguating segment of the input sentence. It will not be crucial in the discussion whether the mental representation holds only one interpretation, as in a serial model in which only one interpretation is pursued at a time (Frazier & Fodor, 1978; Gorrell, 1995; Pritchett, 1992), or more than one interpretation as in a ranked parallel model where various interpretations are constructed simultaneously and ranked according to some metric (Gibson, 1991; Gorrell, 1989).

Several models of reanalysis have considered the type and amount of change performed on the mental representation in order to explain difficulty in the reanalysis process. Although *change* has been characterized in different ways by each specific proposal, these models have in common the emphasis they put on the process of transforming the old mental representation into a new one compatible with the disambiguating segment. For example, some proposals have characterized types of changes in terms of the configurations of tree nodes before and after reanalysis (Gorrell, 1995; Pritchett, 1992), or in terms of the operations allowed in the manipulation of tree structures (Sturt & Crocker, 1996). Other proposals have quantified change in terms of the numbers of NPs that are displaced in the tree structures during reanalysis (A. Inoue, 1991; Mazuka & Itoh, 1995).

In contrast to the proposals above, Fodor & A. Inoue (1994) suggested that the process of changing the mental representation per se is irrelevant and that difficulty during reanalysis is determined by the clarity of the disambiguating segment alone (see also Frazier & Rayner, 1982). In this view, the reanalysis process should be easy independent of the type and amount of change it involves as long as the disambiguating segment is clear as to what the new most-favoured interpretation should be.

Contrary to Fodor and Inoue's proposal, it will be argued here that difficulty during reanalysis is influenced by the process of manipulating tree structures, and in particular,

that it correlates with the amount of change executed on the trees, although clarity of the disambiguating region may also be a factor. Experiment I examines this question in a construction in Japanese with a main/relative clause ambiguity.

Given the result in Experiment I that amount of change correlates with difficulty during reanalysis, the second question investigated is the following. During reanalysis, the parser may have several alternative interpretations to choose from. The question then is whether the parser's choices are affected by the amount of change (and hence difficulty) that each alternative interpretation entails. In particular, in what will be referred to here as the *minimal change strategy* (MCS), it has been proposed that, during reanalysis, the parser attempts to maintain the original representation as much as possible by performing the fewest changes that guarantee a well-formed representation (*minimal revisions* in Frazier, 1990, 1994; *minimal everything* in A. Inoue & Fodor, 1995). The literature in Japanese sentence processing in particular has used special cases of the MCS to explain preferences in the resolution of main/relative clause ambiguities (A. Inoue, 1991; Mazuka & Itoh, 1995). In an alternative view to the MCS, it can be argued that decision-making in reanalysis is independent of amount of change (even if more changes lead to more difficulty) and that the parser chooses an interpretation guided by various types of constraints such as discourse simplicity, plausibility, lexical frequency, grammar requirements (Altmann & Steedman, 1988; Gibson & Pearlmutter, 1998; MacDonald, Pearlmutter & Seidenberg, 1994). The present chapter will argue for this second type of approach, but it will not explore the interplay of different types of constraints during reanalysis. Instead it will focus on the subcategorization requirements of verbs and its counterpart requirement for NPs to be associated with a predicate. Similarly to what has been proposed for first-pass mode (Gibson, 1991; Pritchett, 1992), it will be assumed that subcategorization constraints have to be maximally satisfied at each point during reanalysis as well. Experiments II and III investigate the choices made by the parser during reanalysis in a Japanese construction with a main clause/sentential complement ambiguity.

The chapter is organized as follows. The next section briefly describes how the amount of change in the mental representation has been used in the Japanese sentence processing literature in order to explain reinterpretation preferences as well as difficulty. The following section provides evidence for a correlation between amount of change and reanalysis difficulty

by reporting a self-paced reading experiment (Experiment I) based on constructions due to Mazuka & Itoh (1995). This result will be used to argue against the proposal that clarity of the disambiguating signal is the only source of reanalysis difficulty (Fodor & A. Inoue, 1994). Next, a self-paced reading experiment (Experiment II) and a questionnaire (Experiment III) argue against the hypothesis that amount of change determines the interpretation favoured by the parser. The overall conclusion will be that amount of change executed during reanalysis contributes to difficulty, but it does not affect how the parser chooses among possible interpretations.

1.2 Processing relative clauses in Japanese

Whenever possible, Japanese speakers interpret a sequence of NPs followed by a verb as a single clause (Yamashita, 1994). This initial preference follows from various principles proposed in the sentence processing literature such as *minimal attachment* (Frazier & Fodor, 1978), *properties of thematic reception* (Gibson, 1991), *simplicity* (Gorrell, 1995), *the principle of theta attachment* (Pritchett, 1992). However, when the parser detects a noun after the simple clause it just constructed, it has to create a relative clause (RC). Consider how the parser may change from a single clause (as in Example (1a)) into a double clause interpretation (as in Example (1b)).[1]

Example (1)

a. [Obasan-ga toshiyori-o mita.]
woman-Nom old-man-Acc saw
"The woman saw the old-man."

b. Obasan-ga [$_{RC}$ t_i toshiyori-o mita] onnanoko$_i$-ni koe-o-kaketa
woman-Nom old-man-Acc saw girl-Dat called
"The woman called the girl who saw the old-man."

At the point where the verb **saw** is read in Example (1b), the preferred interpretation is the simple clause **The woman saw the old-man.** At **girl**, it is clear that this noun is the head of a RC. The following Examples (2b) and (2c) show two possible interpretations for the RC

[1]The following abbreviations will be used to indicate Japanese particles (e.g., case markers, postpositions, etc): Nom for nominative, Acc for accusative, Dat for dative, Loc for locative, Top for topic, Comp for complementizer.

created at that point.

Example (2)

a. [Obasan-ga toshiyori-o mita] ⟵ onnanoko-ni
   woman-Nom old-man-Acc saw girl-Dat

b. *Expulsion of one NP (the subject* woman)
   Obasan-ga $[_{RC}$ t_i thoshiori-o mita] onnanoko$_i$-ni
   woman-Nom old-man-Acc saw girl-Dat

c. *Expulsion of two NPs (the subject* woman *and the object* old-man)
   Obasan-ga toshiyori-o $[_{RC}$ t_i pro mita] onnanoko$_i$-ni
   woman-Nom old-man-Acc saw girl-Dat

In Example (2b), the RC means **the girl who saw the old-man** and the NP **woman** is part of the main clause as intended in Example (1b). In Example (2c), **woman** and **old-man** are in the main clause and the RC does not make clear what or who the **girl** saw: **girl who saw (pro)**. (This latter interpretation is not compatible with Example (1b) because **called** does not subcategorize for the accusative NP **old-man**, but it would be correct if the main verb was, for example, **introduced**, yielding: **the woman introduced the old-man to the girl who saw (pro)**.) To explain the preference that native speakers have for Example (2b) over Example (2c), A. Inoue (1991) proposed that a serial parser tries to expel as few NPs as possible from the original simple clause interpretation (**the woman saw the old-man**).

Minimal expulsion: The parser attempts to expel the least number of arguments from a clause during reanalysis.

Minimal expulsion is a special case of the *minimal change strategy* (MCS) which proposes that the parser tries to maintain the original interpretation whenever possible by minimizing the amount of change to be performed. In addition, Mazuka & Itoh (1995) suggested that not only is there a preference to expel as few NPs as possible, but also that syntactic restructuring is perceived as hard if the parser is forced to expel two or more NPs. Consider the following sentences adapted from Mazuka & Itoh (1995). See Figures (1.1), (1.2) and (1.3) for the respective tree structures.

Example (3)

a. Simple clause

Obasan-ga toshiyori-o kousaten-de mita.
woman-Nom old-person-Acc intersection-Loc saw

"The woman saw the old-person at the intersection."

b. Subject reanalysis (SR)

Obasan-ga $[_{RC} t_j$ toshiyori-o kousaten-de mita] onnanoko$_j$-ni koe-o-kaketa.
woman-Nom old-person-Acc intersection-Loc saw girl-Dat called

"The woman called the girl who saw the old-person at the intersection."

c. Subject and object reanalysis (SOR)

Obasan$_i$-ga toshiyori-o $[_{RC} t_i$ t_j kousaten-de mita] takushii$_j$-ni noseta.
woman-Nom old-person-Acc intersection-Loc saw taxi-Dat put

"The woman put the old-person in the taxi which she saw at the intersection."

Up to the verb **saw**, the three sentences in Example (3) are exactly the same on the surface and at this point a simple clause interpretation as in Example (3a) is favoured. When the nouns **girl** and **taxi** are read in Examples (3b) and (3c) respectively, they have to be interpreted as the heads of an RC. In Example (3b), as in Example (1b) above, the preference is to expel the subject NP **woman**. In Example (3c), however, both the subject **woman** and the object **old-man** have to be shifted out of the simple clause. Based on native speakers' judgements, Mazuka & Itoh (1995) claimed that reanalysis in (b) is easy because it entails displacing only one NP while in (c) reanalysis is hard because two NPs have to be expelled. Note that this proposal (as well as minimal expulsion) is only concerned with the position of the overt NPs in the tree structure and it is immaterial that the NPs may still be the argument of the embedded verb through a chain (e.g., in Example (3c) the trace t_i indicates that the entity **woman**$_i$ remains as the subject of the embedded verb **saw**, but for the present proposal, it is only the position of the NP **woman** outside the embedded clause that matters). Example (3b) will be referred to as SR (subject reanalysis) and Example (3c) as SOR (subject and object reanalysis).

The adverb **at the intersection** is important in Example (3c) as it guarantees that the parser will not consider the interpretation in which **taxi** was extracted from a locative inside the RC. In other words, if **at the intersection** was removed, the RC could be temporarily interpreted

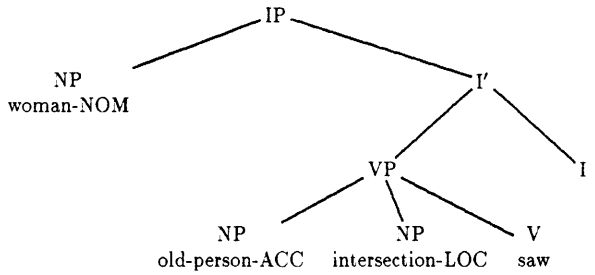

Figure 1.1: Tree for Example (3.1a): "The woman saw the old-person at the intersection."

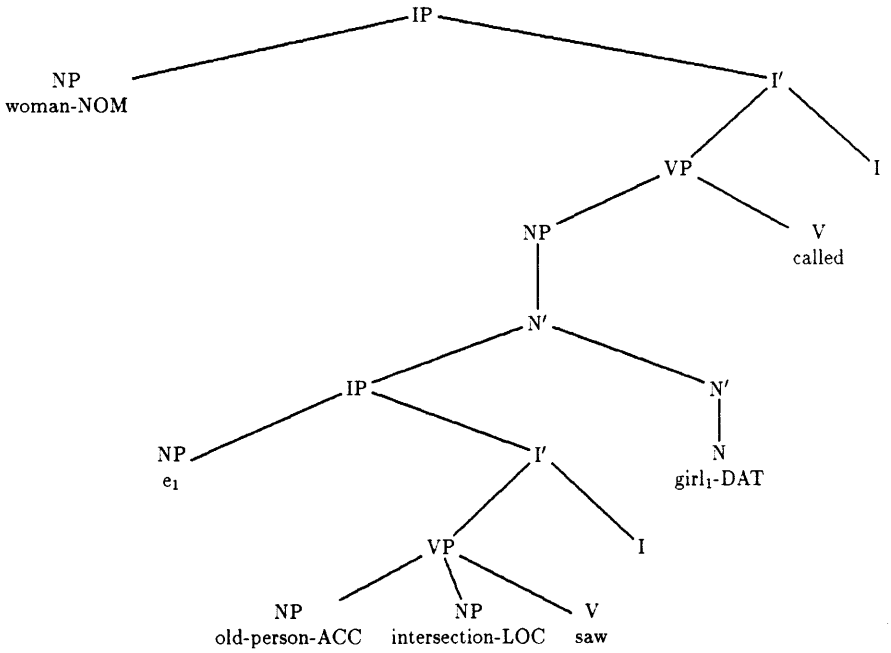

Figure 1.2: Tree for Example (3.1b): "The woman called the girl who saw the old-person at the intersection."

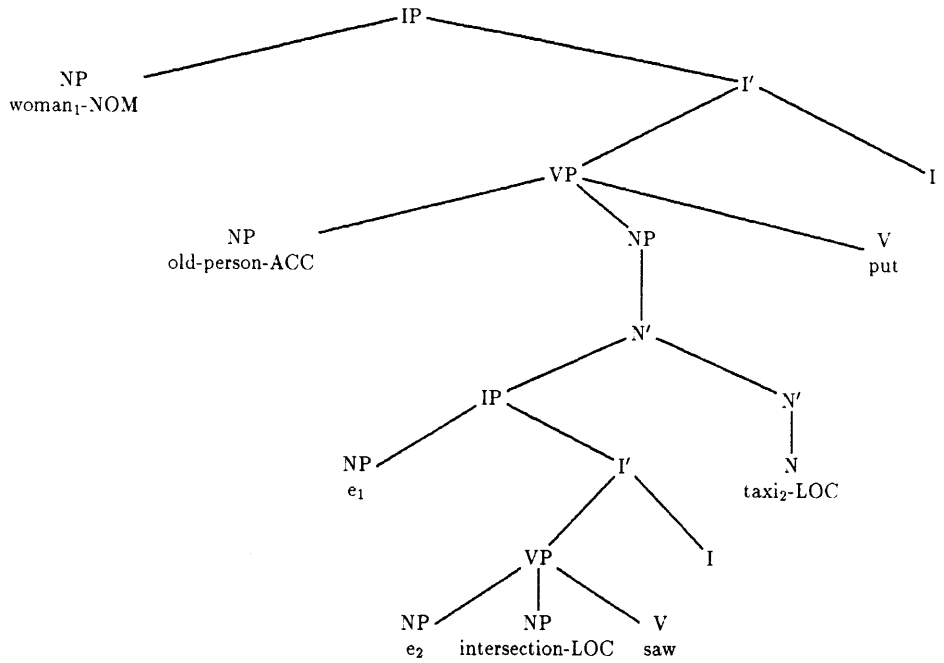

Figure 1.3: Tree for Example (3.1c): "The woman put the old-person in the taxi which she saw at the intersection."

as meaning the taxi in which the woman saw the old-person. (See Sturt & Crocker, 1996, for a discussion on a garden-path effect *at the end of the sentence* if this latter interpretation is assumed by the parser. In Example (3c), the difficulty is claimed to occur immediately at the RC head.)

Considering the proposals above by Inoue and by Mazuka and Itoh, the present paper investigates whether amount of change performed during reanalysis correlates with difficulty (Experiment I) and whether it influences the interpretation favoured by the parser (Experiments II and III).

The proposals above were made under a serial processing model, in which the mental representation holds one single tree structure at a time, and therefore change performed on the mental representation in these cases is a shorthand for the transformations that the old tree structure must undergo in order to yield a new tree whose interpretation conforms with the disambiguating segment. But change may not be inherent to serial processing only. In ranked parallel models (Gibson, 1991; Gorrell, 1989), changing a tree structure per se is usually not a necessary concept as all potential trees/interpretations may be built

simultaneously. But because the interpretations are ranked according to a metric, change may be recast in terms of the similarity between the most favoured tree structures before and after reanalysis. It is not the purpose of this paper to advocate either framework, but the questions discussed here are not of exclusive interest to serial models only as it has often been assumed in the literature. The following sections will remain neutral on this issue allowing the results to be interpreted under either type of model.

1.3 Experiment I — number of NPs displaced as an indicator of difficulty

The present experiment investigates Mazuka and Itoh's intuition that processing of SR sentences (Example (3b)) is easier than SORs (Example (3c)). If this is the case, this result would support the view that amount of change (measured in number of NPs displaced) influences difficulty.

1.3.1 Method

Participants

Twenty-seven native speakers of Japanese participated in the experiment. They were residents in the Kansai area and graduate students in Information Science at NAIST (Nara Institute of Science and Technology). Three were eliminated from the analysis because of their reading patterns (see analysis section below for details).

Materials

Examples (3b) and (3c) are repeated below as Examples (4a) and (4c), except that the first nominative case marker is replaced by a topic marker, and adjectives and adverbs were added; Examples (4b) and (4e) were used as their respective controls. All items were presented using Japanese characters as can be seen in the list of stimuli in Appendix 1-B.

Example (4)

Regions for the self-paced reading presentation:

1	2	3	4	5	6	7	8	9

a. SR (subject reanalysis)

Obasan-wa	[$_{RC}$	yoboyobo-no	toshiyori-o	guuzen-ni	kousaten-de	mita]	onnanoko-ni	isoide	koeo-kaketa.
woman-Top		feeble	old-man-Acc	by chance	inters.-Loc	saw	girl-Dat	hurry	called

"The woman called hurriedly the girl who saw the feeble old-man at the intersection by chance."

b. Control for SR

Obasan-wa	[$_{RC}$	yoboyobo-no	toshiyori-ga	guuzen-ni	kousaten-de	mita]	onnanoko-ni	isoide	koeo-kaketa.
woman-Top		feeble	old-man-Nom	by chance	inters.-Loc	saw	girl-Dat	hurry	called

"The woman called hurriedly the girl who the feeble old-man saw at the intersection by chance."

1	2	3	4	5	6	7	8	9

c. SOR (subject and object reanalysis)

Obasan-wa	yoboyobo-no	toshiyori-o	[$_{RC}$	guuzen-ni	kousaten-de	mita]	takushii-ni	isoide	noseta.
woman-Top	feeble	old-man-Acc		by chance	inters.-Loc	saw	taxi-Dat	hurry	put

"The woman put the feeble old-man hurriedly in the taxi that she saw at the intersection by chance."

d. Unscrambled control for SOR

Obasan-wa	yoboyobo-no	toshiyori-o	[$_{RC}$	gakusei-ga	kousaten-de	mita]	takushii-ni	isoide	noseta.
woman-Top	feeble	old-man-Acc		student-Nom	inters.-Loc	saw	taxi-Dat	hurry	put

"The woman put the feeble old-man hurriedly in the taxi that the student saw at the intersection."

e. Scrambled control for SOR

Yoboyobo-no	toshiyori-o	obasan-wa	[$_{RC}$	gakusei-ga	kousaten-de	mita]	takushii-ni	isoide	noseta.
feeble	old-man-Acc	woman-Top		student-Nom	inters.-Loc	saw	taxi-Dat	hurry	put

"The feeble old-man, the woman put hurriedly in the taxi that the student saw at the intersection."

In Japanese, NPs can be topicalized with the case marker **wa**. Although the subject of the main clause is not the only NP that can be topicalized, there seems to be a preference to interpret an NP marked by **wa** as being the subject. Under this assumption, the processing of the above sentences should procede as follows.

The difference between Examples (4a) and (4b) is in the case marker of the third word (**old-man**), which will lead to different interpretations when the verb **saw** is read. Example (4a) is an SR sentence, hence, reanalysis should take place at the seventh word (**girl**) in order to shift the subject **woman** to the main clause. In (b), however, the reader is likely to know in advance (before reading **girl**) that this is not a single-clause sentence because the nominative marker on **old-man** suggests the presence of another clause. Here, when **saw** is read, its subject has to be **old-man**, while **woman** must be the subject of an outer clause. In this case, no surprise effect should occur when the word **girl** is read since this would be the

expected head of the RC (i.e., **the girl who the feeble old-man saw**). The difference between the reading times of the seventh word **girl** in these two conditions should indicate whether there is in fact any reanalysis difficulty in the SR sentence.

The reasoning is similar for Example (4c) and its control Example (4e). Example (4c) is a SOR sentence, thus reanalysis at **taxi** has to expel the subject **woman** and the object **old-man**. Reanalysis does not occur in (e) because the verb **saw** cannot take three NPs as arguments, hence, the reader should know that there are two clauses in this sentence before reaching the word **taxi**. Due to its position, the nominative NP **student** is interpreted as the subject of **saw**. The reading time of the seventh word (**taxi**) should determine the extent of difficulty in the SOR sentence.

Mazuka and Itoh's intuition that reanalysis in sentences of the SOR type is harder than in the SR type will be confirmed if the difference in reading times of the word **taxi** between (c) and its control (e) is significantly larger than the difference in reading times of **girl** between (a) and its control (b). Such an interaction effect would support the hypothesis that displacing two NPs in SORs is harder than displacing one NP in SRs, or more generally, that reanalysis gets harder as the number of changes increases.

Example (4d) is similar to Example (4e), except that in the latter, the object NP **feeble old-man** was scrambled to the beginning of the sentence. Example (4d) was the initial control considered for Example (4c), but a local ambiguity still remains here since **old-man** could be part of either the RC or the main clause. In other words, in (d), when the verb **saw** is read, **old-man** might be temporarily interpreted as its object and some reanalysis could still occur when **taxi** is read. There was an additional worry that the somewhat unusual word order in (e), with the topicalized NP (**woman**) after the accusative NP, could cause some processing difficulty. Hence, condition (d) was also included in order to assess possible slow-downs in (e).

The difficulty in controlling for local ambiguities in this experiment is an instance of a more general issue in that there is no single straightforward way of signalling the beginning of a RC in Japanese (see A. Inoue, 1991, for a detailed discussion). In this experiment, the control sentences involve the use of sequences of NPs whose case markers do not match the argument structure of the following verb. These controls may involve some reanalysis

since they necessarily present an unexpected element at some point in order to indicate the presence of more than one clause. The assumption here is that the parser resumes its usual processing speed after reanalysis takes place in the control sentences, or at least enough to provide a reasonable baseline for the test sentences.

This assumption is not always correct as attested in an earlier version of this experiment. A self-paced reading experiment was conducted with the sentences in Example (4) except that woman was marked with nominative case (**ga**) in all conditions instead of the topic **wa**. This experiment yielded a null result as no differences were detectable at the RC heads. This could be because of the difficulty in processing the two nominative NPs in the control sentences which might have disrupted the processing of the following words. See Appendix 1-A for the results of this earlier version of Experiment I and a discussion on the processing of double nominatives in Japanese. In order to avoid the double nominative effect, topicalization was used to replace the first nominative case marker as can be seen in Example (4).[2]

Procedure

The experiment was conducted on Psyscope (Cohen, MacWhinney, Flatt & Provost, 1993) running on a Power Macintosh 8100/81AV or a Power Macintosh 7500/100. The self-paced reading moving-window program presented sentences (Just, Carpenter & Woolley, 1982), one word at a time (to be more precise, a word plus possible particles such as case-markers) on a single line in a non-cumulative fashion, and was based on a script for English sentences

[2]Mazuka and Itoh pointed out that a topicalized NP is not inside the simple clause for the purposes of their proposal, but instead adjoined to its left, as schematically represented in Example (5b) below, therefore already outside the clause constructed.

Example (5)

a. [Obasan-ga toshiyori-o mita]
   woman-Nom old-man-Acc saw
   "It's the woman who saw the old man."

b. Obasan$_i$-wa [t$_i$ toshiyori-o mita]
   woman-Top old-man-Acc saw
   "The woman$_i$, she$_i$ saw the old man.

This suggests that the topic NP in (b) might not have to be expelled during reanalysis. However, an experiment was conducted comparing Mazuka and Itoh's sentences (Example (4c) in particular) with topic versus nominative case marker on the first NP, but no differences were found. Therefore it is assumed here that even topicalized NPs are expelled during reanalysis.

provided by K. McRae. Participants pressed the leftmost button of the button-box to reveal each subsequent word and cause all other words to revert to dots. A yes/no question was presented after each sentence without feedback. The font used was Osaka Touhaba 14.

The experimental trials were preceded by one screen of instructions and eight practice trials. The experiment took participants approximately 20 minutes. Participants read six sentences for each of the five conditions in a Latin Square design. These 30 sentences were intermixed with 90 unrelated items in pseudo-random order. See Appendix 1-B for the list of test stimuli used.

Data analysis

Analyses were performed on comprehension question response accuracy and on reading times (both raw and residual). The analyses only included the items for which the participants answered the comprehension question correctly. A linear regression between word lengths and reading times was performed on each participant's data set (Ferreira & Clifton, 1986). The portion of the reading time predicted by the length of the word was subtracted from the original raw reading time, yielding a residual reading time (RRT). The RRT obtained in this way can be a positive or negative number, which indicates by how much the participants diverged from their individual average reading time for a word of that length. Furthermore, the data were trimmed so that data points beyond 3.5 standard deviations from the relevant condition $\times$ region cell mean were discarded, corresponding to less than 2% of the data. The means and the analyses of variance presented here are based on the trimmed residual reading times. The analysis on the raw reading times revealed patterns similar to the RRT results.

Overall, the reading times collected in self-paced reading experiments in Japanese are markedly slower than in English. However, the average reading times per word often observed in English self-paced reading (around 350 ms) includes content as well as function words. Since English speakers read the latter much faster than the former, it should not be surprising that the average reading times in Japanese (in which a "word" is in fact composed of a content word plus a functional particle) are larger.

Two participants were eliminated for being the only ones presenting negative slopes when

the residual reading times were calculated (-9.86 ms and -69.3 ms). A third participant was eliminated for having an intercept of 2710 ms, while the rest of the participants had intercepts between 259 and 1232 ms (M = 717; SD = 208).

No crucial claims will be made based on the reading times of the main verb of the items. This is for two reasons. First, the main verb is always the last word in the sentences. Although reading times of such words may be useful in some contexts, they could include sentence final wrap-up effects, which may cause spurious delays. Second, in some items, where the main clause required a ditransitive verb, verbs in the passive were used instead. In Japanese, simple passives, causatives (equivalent to "make/force somebody do something") and adversatives ("was affected negatively by...") can only be detected at the verb. The use of these various types of passives added a confound as an independent study suggested that they may be processed more slowly.

1.3.2 Results

The percentages of correct responses are given in Table 1.3.2. The difference between condition SR (A) and its control (B) was not significant ($F_1(1,23) = 2.61$, $p = 0.120$; $F_2(1,29) = 2.03$; $p = 0.165$). The differences were also not significant between SOR (C) and its scrambled control (E) ($F_1(1,23) = 3.45$, $p = 0.076$; $F_2(1,29) = 1.174$, $p = 0.288$) or its unscrambled control (D) ($F_1(1,23) = 2.52$, $p = 0.126$; $F_2(1,29) = 1.23$, $p = 0.277$).

Condition	A	B	C	D	E
Correct responses (%)	81.5	73.5	64.8	71.6	72.8

Table 1.1: Experiment I: rate of correct responses

Figures 1.4 and 1.5 present the mean residual reading times with standard errors as obtained in the analyses by subjects. The analysis for the seventh word in the sentences, i.e., the head-noun of the RCs (**girl** and **taxi**) yielded the following results. (In the analysis *per items*, four items had to be ignored for not having enough data points, which were lost during the trimming procedure.) The interaction between ambiguity and number of NPs in the main clause was significant in AB×CE ($F_1(1,23) = 16.3$, $p < 0.01$; $F_2(1,25) = 8.100$, $p <$

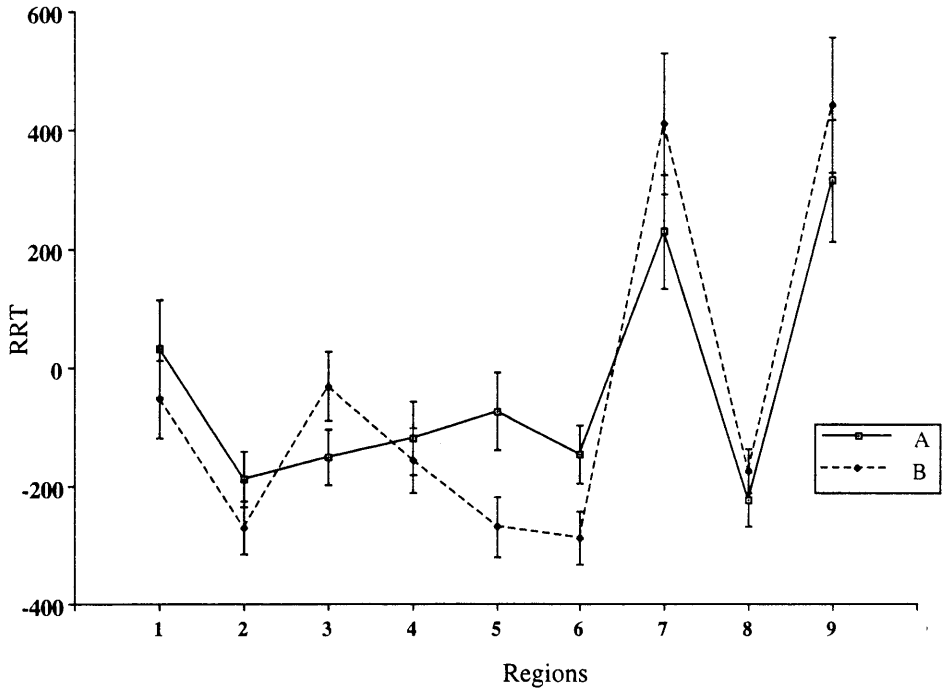

Figure 1.4: SR sentences (A) and controls (B): mean residual reading times and standard errors by subjects. Region 7 contains the RC head.

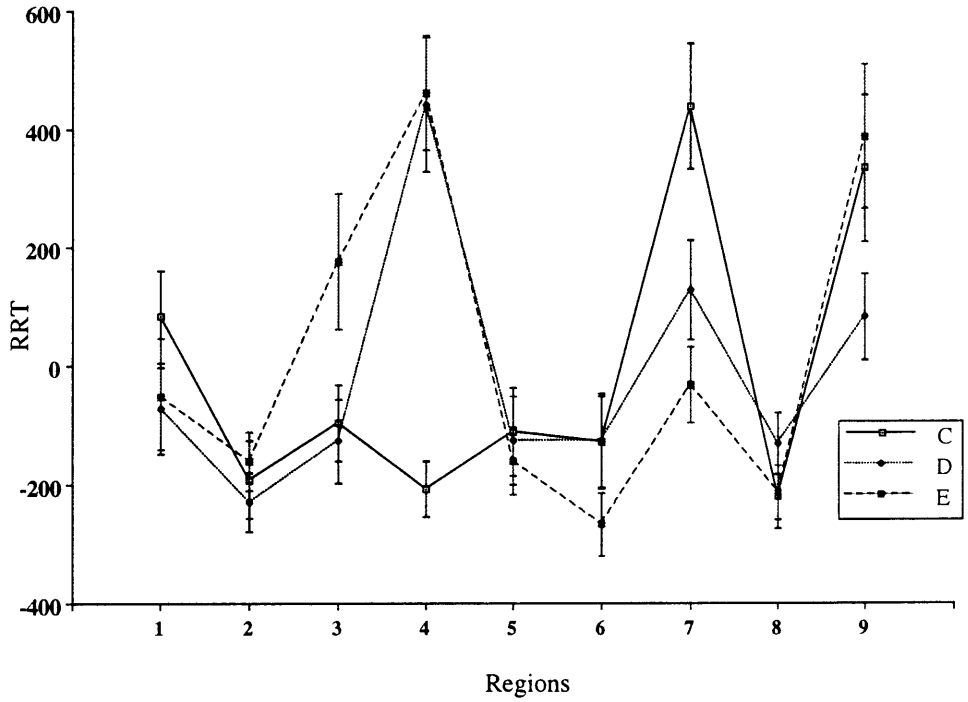

Figure 1.5: SOR sentences (C) and controls (D, E): mean residual reading times and standard errors by subjects. Region 7 contains the RC head.

0.01) and marginally in AB×CD ($F_1(1,23) = 11.7$, $p < 0.01$; $F_2(1,25) = 3.827$, $p = 0.062$), where (E) is the condition with scrambling and (D) without. Such interactions come from the difference between the SOR condition and its controls (D, E) with two NPs in the main clause: SOR (C) was significantly slower than its scrambled control (E) ($F_1(1,23) = 19.2$, $p < 0.01$; $F_2(1,25) = 9.62$, $p < 0.01$) and marginally slower than its unscrambled control (D) ($F_1(1,23) = 7.80$, $p < 0.05$; $F_2(1,25) = 3.62$, $p = 0.069$). Condition (D) is only numerically slower than (E) ($F_1(1,23) = 2.55$, $p = 0.124$; $F_2(1,25) = 2.495$, $p = 0.127$). Moreover the conditions with one NP in the main clause, SR (A) and its control (B), are not significantly different ($F_1(1,23) = 2.56$, $p = 0.123$; $F_2 < 1$). These results are displayed in Table 1.3.2 for ease of reference.

Conditions	$F_1(1,23)$	p	$F_2(1,25)$	p
A × B	2.56	0.123	0.88	0.357
C × D	7.80	0.05 *	3.62	0.069
C × E	19.2	0.01 *	9.62	0.01 *
D × E	2.55	0.124	2.49	0.127
AB × CD	11.7	0.01 *	3.83	0.062
AB × CE	16.3	0.01 *	8.10	0.01 *

Table 1.2: Experiment I: ANOVA results for word 7

As observed earlier, the control sentences involve some difficulty before region 7 when they indicate that the sentence is likely to have more than one clause. This is particularly clear in region 4 (Figure 1.5), at which point the nominative NP in the controls D and E is read significantly slower than the adverb in the SOR sentences (condition C) both by subjects as well by items (ps < 0.01). Moreover, in region 3, the topicalized NP in the control E is slower than the accusative NP in D (ps < 0.05 by subjects and by items) as should be expected given that topicalized NPs do not usually occur in the middle of sentences.

1.3.3 Discussion

The significant interaction found (AB × CE) suggests that the number of NPs expelled correlates with slow-down during processing as apparently the extra NP expelled in the

SOR sentences makes reanalysis harder than in the SR sentences. Both conditions SR (A) and SOR (C) are ambiguous, and the shifting of one or two NPs has to take place during reanalysis whereas the unambiguous controls (B and E) provide baseline reading times for the RC heads. This result supports Mazuka and Itoh's proposal that displacing one NP is easy (as in condition (A)), while displacing two NPs is hard (condition (C)). In more general terms, it suggests that the amount of change performed has influence on the difficulty of carrying out reanalysis.

Although not statistically significant, the difference between conditions (D) and (E) at **taxi** suggests that the local ambiguity in (D) seems to have an effect on processing time. These two conditions were supposed to be unambiguous with the difference that (E) had the accusative NP **feeble old-man** scrambled to the beginning of the sentence, while in (D) there was the possibility that the accusative NP would be interpreted as being part of the RC when **saw** was read.

In the comparison between SR and its control (B), it is being assumed that there is no difference in the time to process RCs whether the subject or the object was relativized. In English, it is known that this assumption is not correct and that RCs with an object gap are harder to process (e.g., King and Just, 1991). If this parsing difference is related to a universal factor such as the Accessibility Hierarchy (Keenan & Comrie, 1987) then a new control sentence will be needed for the SR condition. However, if object gaps are harder to process in head initial languages because they are farther from the RC filler than subject gaps (Gibson, 1998), then this difference may not be observable in Japanese, a language where gaps in RCs may be PROs (Murasugi (1991)). But this topic needs to be further investigated.

Regardless of the status of condition (B), the significant slow-down detected at the RC head of condition SOR (C) compared to (E) suggests that SOR is indeed a garden path sentence. The following subsection considers an alternative interpretation for the slow-down found in (C) based on Fodor and Inoue's Diagnostic Model.

Animacy of the relative clause head

An alternative explanation for the interaction found in this experiment comes from the proposal in Fodor & A. Inoue (1994) that the clarity of the disambiguating signal is the only source of difficulty during reanalysis. In the present case, it could be suggested that the RC head taxi in the SOR condition can be interpreted as an agent or a theme, and hence it does not indicate clearly to the parser whether the RC should be constructed with an object or a subject gap. The slow-down detected then would stem from this uncertainty of which interpretation(s) to pursue, thus, amount of change per se would be irrelevant to explain the difficulty with SOR sentences. This section provides evidence that the clarity of the disambiguating segment is not enough to explain the result in Experiment I and that some other factor such as amount of change has to be taken into consideration.

Supporting Fodor and Inoue's proposal, Hirose (1997) and Hirose & Inoue (1997) provide some evidence that the difficulty in processing SOR sentences can be modulated by varying the animacy of the RC head. When the RC head is clearly an inanimate noun, reanalysis becomes easier as the RC head must be associated with an object and not a subject gap inside the RC. In a self-paced reading experiment (Hirose & Inoue, 1997), using SOR sentences, the underlined inanimate NP in Example (6b) below was read significantly faster than the animate NP in Example (6a), although the amount of change (i.e., the number of NPs being expelled) in each sentence at that point is exactly the same.

Example (6)

a. *SOR with animate RC head*
Yamaoka-ga kakushiisan-o [anotekonotede sagashidashita] mogurino bengoshi-ni yamunaku azuketa.
Y.-Nom fortune-Acc great-effort discovered unlicensed lawyer-Dat unwilling entrusted

"Yamaoka unwillingly entrusted his fortune to the unlicensed lawyer who he discovered after great effort."

b. *SOR with inanimate RC head*
Yamaoka-ga kakushiisan-o [anotekonotede sagashidashita] mogurino kashikinko-ni yamunaku azuketa.
Y.-Nom fortune-Acc great-effort discovered unlicensed safe-Dat unwilling entrusted

"Yamaoka unwillingly entrusted his fortune to the unlicensed safe that he discovered after great effort."

Hirose and Inoue's result is in accordance with Fodor and Inoue's proposal but it does not guarantee that the clarity of the disambiguating signal is the only source of reanalysis

difficulty. In particular, their result does not rule out the possibility that number of NPs expelled may also contribute to slow-downs during reanalysis. In the following, a more detailed analysis of Experiment I provides evidence that, even when the RC head is unambiguously inanimate, displacement of two NPs is harder than displacement of one NP.

In Experiment I, the SR and SOR conditions expelled one and two NPs respectively during reanalysis (see Example (4)). If all the items in the SOR condition had inanimate heads, then this condition would be equivalent to Hirose and Inoue's Example (6b). Because the inanimate head would unambiguously indicate the kind of RC to be constructed, then according to Fodor and Inoue, reanalysis should be as easy as in SRs. However, if the number of NPs expelled is a factor weighing in reanalysis difficulty, then slower reading times should be detectable at the inanimate RC head in SORs compared to SRs.

In Experiment I, five SOR items (condition C) had ambiguous RC heads as they could be interpreted as the subject or the object of the embedded verb. In the other 25 items, the RC head could only be interpreted as the object of the verb. If Fodor and colleagues are correct, then a new analysis including only the latter 25 items should not yield a significant interaction. But if the number of NPs expelled is an independent factor, then this new analysis should still yield significant differences. The pattern of results of the new analysis was the same as in the original: the interaction of conditions AB×CE was significant by subjects ($F_1(1,23) = 15.2$; $p < 0.01$) as well as by items ($F_2(1,21) = 5.50$; $p < 0.05$). Crucially the slow-down in condition SOR (C), which corresponds to Hirose and Inoue's Example (6b), was significant when compared to the scrambled control (E) by subjects ($F_1(1,23) = 22.5$, $p < 0.01$) and by items ($F_2(1,21) = 6.93$, $p < 0.05$).

This new analysis suggests that the number of NPs expelled from a clause affects difficulty in reanalysis independent of animacy ambiguities at the RC head. In this case, Hirose and Inoue's result can be interpreted as indicating that uncertainty during reanalysis is one factor (but not the only one) influencing difficulty. Therefore, contrary to what Fodor and Inoue propose, amount of change during reanalysis or in more general terms the process of changing the mental representation does seem to have an impact on the difficulty level of reanalysis.

1.4 Maximal grammaticality and minimal change

The present chapter addresses two issues. In terms of reanalysis difficulty, Experiment I supports the view that the amount of change executed on the mental representation correlates with slow reading times and consequently with difficulty. Given this initial result, it seems natural to suggest that the parser may minimize change (hence minimizing difficulty) when choosing the most-favoured interpretation among the various alternatives that may be available during the reanalysis process.

In a proposal such as the *minimal change strategy* (MCS), the parser during reanalysis favours the interpretation that requires the fewest changes to be executed on the mental representation (Frazier, 1994; A. Inoue, 1991), in other words, a serial parser may make incremental changes in the tree structure and may stop as soon as the new tree can accommodate the word(s) in the disambiguating region. Consider Example (2) repeated below as Example (7).

Example (7)

a. [Mary-ga John-o mita] ⟵ onnanoko-ni
   Mary-Nom John-Acc saw girl

b. Expulsion of one NP (Mary-ga)
   Mary-ga $[_{RC}$ t_i John-o mita] onnanoko$_i$-ni

c. Expulsion of two NPs (Mary-ga and John-o)
   Mary-ga John-o $[_{RC}$ t_i pro mita] onnanoko$_i$-ni

Given the initial single clause interpretation in Example (7a), the MCS justifies native speakers' preference for (b) over (c) when the RC head **girl** is encountered because (b) requires only one change, namely, only one NP (**Mary**) has to be displaced. In procedural terms, a serial parser may be displacing NPs one by one, stopping as soon as a coherent interpretation is obtained. Because expelling the first NP **Mary** from the simple clause is sufficient to provide a grammatical interpretation, the parser stops at this point and does not attempt to expell the second NP, which would have yielded (c). (See also tree-lowering in Gorrell, 1995; Sturt & Crocker, 1996.) However, note that the extra change executed in Example (7c) does not cause more grammatical constraints to be satisfied (in fact, it has more grammatical violations because the NP **John** does not have a theta-role at this point in this interpretation),

and in that sense it is a vacuous change. This observation suggests a different explanation for the preferences in this construction.

In an alternative proposal to the MCS, it may be suggested that the parser does not try to minimize the amount of change during reanalysis, but instead, it attempts to maximally satisfy grammatical requirements as it has been proposed for first pass processing. In particular, consider models in which theta-role assignment or unresolved dependencies have to be optimally satisfied at each processed word (Gibson, 1991, 1998; Pritchett, 1992). Although other factors such as discourse simplicity, plausibility, lexical frequency (Altmann & Steedman, 1988; Gibson & Pearlmutter, 1998; MacDonald, Pearlmutter & Seidenberg, 1994) may also play a role, the focus here will be on verb subcategorization requirements and the counterpart constraint that each argument must be associated with a predicate. In this way, given a disambiguating segment that initiates reanalysis, the parser will attempt to match as best as it can the NPs and the subcategorization frame of the verbs processed so far. Let us refer to this strategy as *maximal grammaticality* or simply MaxG.

Maximal grammaticality (MaxG): once triggered, reanalysis attempts to optimally satisfy the grammatical constraints at each step.

In addition, the parser is conservative and it only makes changes in the mental representation which lead to more constraints to be satisfied.

Constraint driven change (CDC): in reanalysis mode, the parser only makes changes which allow for more constraints to be satisfied.

To some extent, the CDC overlaps with the MCS as both imply that the parser tends to keep the previous connections in the tree structure. However, contrary to the MCS, the favoured interpretation during reanalysis according to MaxG/CDC is determined by grammatical constraints, and difficulty is the product of making the changes necessary to satisfy those constraints. Consider how the MCS and MaxG/CDC account for the processing of a complex noun phrase in Japanese like the following (from A. Inoue & Fodor, 1995).

Example (8)

a. takai kutsu no shuurinin
expensive shoe of repairer
"repairer of expensive shoes" or "expensive repairer of shoes"

b. [takai kutsu] ⟵ no shuurinin

c. [takai kutsu] no shuurinin "repairer of expensive shoes"

d. takai [kutsu no shuurinin] "expensive repairer of shoes"

Example (8a) is ambiguous as the adjective **expensive** may modify either **shoe** or **repairer**. Consider in (b) how the processing of this NP would proceed: initially the adjective is attached to **shoe**, as indicated by the square brackets, but when the next words are processed, the parser has the option of maintaining **expensive** attached to **shoe**, and lowering the whole NP **expensive shoe** as a modifier of **repairer** as shown in (c); or else, the parser can re-attach **expensive** to **repairer of shoes** as in (d). Native speakers' intuition indicates that the preferred reading, in this case, is (c).

The MCS predicts that Example (8d) is less preferred because it requires an extra modification to be performed, namely, breaking the connection between **expensive** and **shoe**. The CDC also makes the correct prediction in this case, because the change being performed in (d) does not increase the grammaticality of the structure. Therefore, according to the CDC, Example (8d) above is the less preferred interpretation not because it requires *more* change as suggested by the MCS, but rather because it requires a *vacuous* change, in other words, a change that does not cause more constraints to be fulfilled.

In essence, MaxG/CDC propose that, during reanalysis, the parser makes a change in the representation if and only if this change allows for more requirements to be satisfied. Therefore the interpretation chosen by the parser is not influenced by the number of operations necessary to realize it, instead the parser aims at the representation that best satisfies the constraints at that point. In this approach, the minimal change aspect often observed during reanalysis is an epiphenomenon; in fact, in what follows, it will be argued that the MCS makes the wrong prediction in some cases because an interpretation involving more changes may be preferred as long as it satisfies more constraints.

1.4.1 Partial interpretation of NPs and reanalysis

Even before a verb is detected, native speakers of Japanesee assign a partial interpretation to a sequence of NPs based on their case markers (Yamashita, 1994). Hence, given the initial segment of a sentence containing three NPs as in Example (9) below, Japanese speakers should know that the sentence must have more than one clause because there is no verb in Japanese that subcategorizes for two nominative and one dative NPs.

Example (9)
Kyouju-ga gakusei-ni toshokanshisho-ga
professor-Nom student-Dat librarian-Nom

When processing such a sequence of NPs, native speakers have to assign each NP to the high (main) clause or to the low (embedded) clause. Considering how native Japanese speakers initially posit such a clause boundary and the reanalysis that may take place at the ensuing embedded verb, it will be possible to tease apart the predictions made by the MCS and MaxG/CDC.

Initial clause boundary assignment

Assuming that for Example (9) above native speakers posit no more than two clauses, the square brackets in the following indicate the two possible ways of assigning the boundary between the main and embedded clauses.

Example (10)
a. Kyouju-ga gakusei-ni [toshokanshisho-ga
professor-Nom student-Dat librarian-Nom
b. Kyouju-ga [gakusei-ni toshokanshisho-ga

Native speakers may prefer the clause boundary in Example (10a) rather than Example (10b), because the nominative NP librarian functions as an indicator of clause boundary; or, in more general terms, consider the following strategy.

Local boundary assignment (LBA): The parser assigns the boundary of a new clause at the point where it is first clear that this new clause is present.

When processing Example (9) above, a simple clause may be initially favoured with **professor** as the subject and **student** as the goal. Once the parser detects the second nominative NP **librarian**, it is clear that the sentence has more than one clause because no verb in Japanese can take two nominative and one dative NPs as arguments. According to the LBA, the parser posits the beginning of the new clause at the first point where it is clear that the sentence is multi-clausal (at **librarian**). Therefore it predicts a preference for Example (10a) over Example (10b).

If the parser already has a partial interpretation for **professor** and **student** as arguments of an incoming verb and therefore it assumes that these NPs are in the same clause, then Example (10b) requires an extra change in order to create a new clause (namely, the lowering of **student** into the new clause). Therefore, although we are calling it a strategy, the LBA can be derived from more general properties of reanalysis, such as the MCS (minimal change strategy) or the CDC (constraint driven change), because the less favoured interpretation requires a vacuous change.

Kamide (1997) provides evidence supporting the LBA by reporting a self-paced reading experiment with globally ambiguous sentences such as Example (11) in which the dative NP **student** can attach either to the the main verb (**showed**) or to the low verb (**lent**). (See also Hirose, 1994, for related results in Japanese; Koh, 1997, for the equivalent structure in Korean.)

Example (11)

Kyouju-ga	gakusei-ni	toshokanshisho-ga	kashita	komonjo-o	miseta
professor-Nom	student-Dat	librarian-Nom	lent	manuscript-Acc	showed

"The professor showed (to the student) the manuscript that the librarian lent (to the student)."

Because the dative NP is optional in ditransitive constructions, it is grammatical to leave the high or the low verb without the dative argument. According to Kamide, in those circumstances, native speakers of Japanese have a preference to attach the dative NP to the main verb, which follows if subjects initially assigned the clause boundary as in Example (10a) as predicted by the LBA.

The parsing of Example (11), then, may proceed as follows. Initially, **professor** and **student** are interpreted as belonging to a single clause. Then, according to the LBA, a new clause

is posited at librarian, leaving student in the high clause. When lent is read, no reanalysis occurs in order to shift student to the low clause because the dative is not an obligatory object of lent. At manuscript, the RC is constructed (the manuscript that the librarian lent). And because student remained in the main clause, its attachment to the main verb showed proceeds as the preferred interpretation.

The above interplay between the LBA and the optionality of the dative explains the result obtained by Kamide. But, clearly, these assumptions make several predictions about reanalysis in Japanese. In the next subsection, some of the predictions are examined in a similar construction.

Re-assignment of clause boundary

If dative NPs are indeed optional in ditransitive constructions, whereas accusative NPs are obligatory, then the LBA would predict that reanalysis should take place in the following sentence.

Example (12)

Shokuin-wa kakarichou-ni ocha-o onnanohito-ga dashita-to shiraseta.
employee-Top manager-Dat tea-Acc woman-Nom served-Comp said
"The employee said (to the manager) that the woman served tea (to the manager)."

Consider how the processing of this sentence proceeds according to the previous assumptions.

Example (13)

a. *Ditransitive clause:*

Shokuin-wa kakarichou-ni ocha-o
employee-Top manager-Dat tea-Acc

b. *LBA - new clause at* woman:

Shokuin-wa kakarichou-ni ocha-o [onnanohito-ga
woman-Nom

c. *Reanalysis of clause boundary:*

Shokuin-wa kakarichou-ni [ocha-o onnanohito-ga dashita-to
served-Comp

Initially, in Example (13a), the parser constructs a single clause ditransitive interpretation. When the nominative NP woman is detected, it is clear that the sentence has more than one clause, and according to the LBA, a clause boundary is assumed at this point, leaving the three previous NPs in the high clause (as in Example (13b)). The verb served is received next,

and although its indirect object is optional, its requirement for a direct object is obligatory. Therefore, the parser reanalyses so that the accusative NP **tea** becomes the direct object of **served** as in Example (13c). This would suggest that the parser prefers to reanalyse and bring **tea** to the low clause, rather than insert a **pro** and make it co-refer with it. (See Koh, 1997, for a different conclusion in Korean.)

In order to explain the result in Kamide (1997), it was proposed above that the human parser is incorporating each incoming word immediately to the mental representation and it only changes a previous attachment if there is enough evidence to do so. Kamide's result suggests that a dative marked NP is not enough to trigger such re-attachment in Example (11). The question investigated in Experiment II is whether an accusative NP can lead to such re-structuring and hence a slow-down in Example (12). Detection of such a slow-down will support the proposal that the parser preferentially constructs the left edge of an embedded clause at the point where it first detects this new clause (LBA), and that reanalysis occurs if the embedded verb requires an accusative argument which was initially interpreted as being part of the high clause.

Although detection of a slow-down at the embedded verb guarantees that reanalysis is taking place in order to lower the accusative NP into the embedded clause, a question remains as to whether the dative NP is also lowered in the process. Here, the predictions made by the MCS and MaxG/CDC differ. The MCS predicts that the dative NP remains in the main clause because just shifting the accusative NP is sufficient to obtain a grammatical sentence (the dative NP is optional, hence it is not required in the low clause). However, MaxG would predict that both NPs should be lowered so that more constraints can be satisfied at this point, in particular, the dative NP would have a theta-role assigned immediately rather than having to wait for the main verb. Those two predictions will be tested in Experiment III.

Experiment I did not tap into the specific differences between the MCS and MaxG. The following two experiments will consider the construction above where the alternative involving fewer changes differs from the interpretation with fewer grammatical violations. If the MCS takes precedence over MaxG, then the former interpretations with fewer changes should be preferred. However, if grammaticality is the crucial factor, then the parser should make the extra change in order to satisfy more constraints.

1.5 Experiment II — clause boundary re-assignment

In this experiment, the LBA is tested by verifying that reanalysis takes place at the embedded verb in Example (12).

1.5.1 Method

Participants

38 native speakers of Japanese, residents in the Boston area, participated in the self-paced reading experiment. They all had completed at least high school in Japan and came to the United States as adults.

Materials

Example (12) is repeated below with an extra adverb as Example (14a). The extra adverb **hurriedly** was inserted to avoid possible spill-over effects as the parser may slow down at the nominative NP **woman**. Example (14b) was used as a control.

Example (14)

Regions for the self-paced reading presentation:

1	2	3	4	5	6	7

a. Shokuin-wa kakarichou-ni ocha-o onnanohito-ga isoide dashita-to shiraseta.
employee-Top manager-Dat tea-Acc woman-Nom hurry served-Comp said
"The employee said (to the manager) that the woman served tea hurriedly (to the manager)."

b. Shokuin-wa [onnanohito-ga kakarichou-ni ocha-o isoide dashita-to] shiraseta.
employee-Top woman-Nom manager-Dat tea-Acc hurry served-Comp said
"The employee said that the woman served tea hurriedly to the manager."

There should be no reanalysis at **served** in Example (14b). This is because the parser would posit the new clause boundary at **woman** and therefore when **served** is read, all of its arguments are already inside the embedded clause.[3] Therefore (b) should provide a baseline

[3]The nominative NP **woman** in Example (14b) does not unambiguously indicate that there is another clause in this sentence, because in some cases it is possible to have a topic and a nominative NPs in a single clause. The sentences below illustrate two of these cases. In (a), the state verb requires that its object be marked with the nominative marker (Kuno, 1973). In (b), the topic NP is not interpreted as a subject but

reading time for the embedded verb **served** to indicate if there is a slow-down at the same word in (a). In addition, note that if during the processing of (a) no reanalysis takes place at **served** then consequently **tea** must have remained in the high clause, and hence a slow-down should be detectable at the main verb **said** as this verb cannot take **tea** as a direct object. Thus, the reading times at the embedded as well as the main verb should indicate whether reanalysis is taking place.

However, even if a slow-down is indeed detected at **served** in Example (14a), it could be suggested that this is not evidence for reanalysis taking place but rather it is because the scrambled word-order (dative – accusative – nominative) in (a) is more difficult to process than the canonical order (nominative – dative – accusative) in (b). However, an independent study suggests that scrambling has an immediate effect on the processing time of the NPs themselves, but that there is no slow-down at the following verb. More specifically, a self-paced reading experiment was conducted with sentences like the following.

Example (16)

a. Ofisu-de shokuin-ga kakarichoo-ni ocha-o dashita ...
   office-at employee-Nom manager-Dat tea-Acc served

b. Ofisu-de shokuin-ga ocha-o kakarichoo-ni dashita ...

Both sentence fragments in Example (16) mean the same (**at the office, the employee served tea to the manager...**), however the word order in (b) is non-canonical (the accusative NP precedes the dative NP), and there is a significant slow down at the fourth word, **manager**, in (b) compared to **tea** in (a). No significant differences were found in the first three words or more crucially at the verb **served**. Similarly, in Mazuka, Itoh & Kondo (1998), the nominative

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rather as an object.

Example (15)

a. John-wa Mary-ga sukida
   John-Top Mary-Nom likes
   "John$_i$, it's Mary he$_i$ likes."

b. John-wa Mary-ga shoutai-shita
   John-Top Mary-Nom invited
   "John$_i$, it was Mary who invited him$_i$."

However, native speakers' intuition suggests that the positing of a new clause at **Mary** is favoured over the single clause alternatives above.

NP in a sequence "NP-Acc NP-Nom " is read slower than the accusative NP in the canonical "NP-Nom NP-Acc ", but no slow-down is observed at the ensuing verb. Therefore in the present experiment, it will be assumed that any slow-down detected at the embedded verb **served** in Example (14a) is not due to word order differences.

In short, a slow-down at **served** in Example (14b) compared to the same word in Example (14a) would support the explanation advanced above for Kamide's result. In particular, it would be evidence that the accusative NP **tea** is initially left in the high clause and is then shifted to the low clause when the embedded verb is read.

Procedure and data analysis

The self-paced reading program was the same used for Experiment I. The same procedure was employed to obtain the residual reading times as discussed previously.

The experiment had a total of five conditions, but only two are reported here. The remaining three conditions examined similar constructions with a transitive embedded verb and were not related to the present claims.

Twenty-five items distributed in a Latin Square design were presented with 44 unrelated items in pseudo-random order. A yes-no question was presented after each item and a message appeared on the screen every time the participant gave an incorrect response, with the corresponding reading times eliminated from the analyses below.

1.5.2 Results

In condition A, participants answered an average of 78.9% of the comprehension questions correctly, and 79.5% in condition B, which are not significantly different (Fs < 1).

As predicted, a slow-down was detected at **served** in Example (14a) in comparison to the same word in Example (14b). The difference was significant by subjects ($F_1(1,37) = 8.999$, $p < 0.01$) as well as by items ($F_2(1,24) = 7.258$, $p < 0.05$). Figure 1.6 provides all the residual reading times. No significant difference was detected at the last word, **said** (Fs <1.2). The same pattern of results was found in the raw reading times.

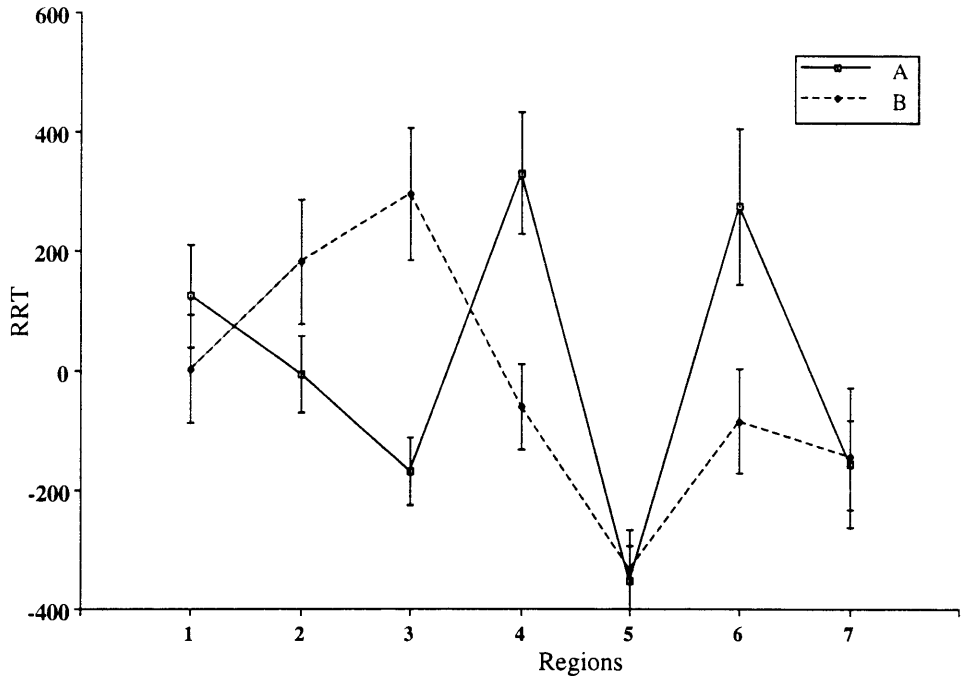

Figure 1.6: Experiment II, conditions A and B.

1.5.3 Discussion

The result confirms the assumption that the parser constructs the left edge of an embedded clause at the point where it first detects this new clause (LBA); and reanalysis at the embedded verb has to take place if any of its obligatory objects are left out in the high clause. In other words, in Example (14a), the slow-down detected at **served** is due to reanalysis as the parser has to displace **tea** from the high to the low clause, so that the subcategorization requirements of **served** can be satisfied.

The lack of significant difference at the last word also supports the hypothesis that **tea** is being shifted to the embedded clause in condition (A). As noted earlier, if **tea** had remained in the high clause, then there should have been a slow-down at the final verb **said** as it cannot take **tea** as a direct object.

Although Experiment II provides evidence for reanalysis taking place at the embedded verb in Example (14a), it leaves a question unanswered. It is not clear whether, during

reanalysis, the dative NP **manager** remains in the high clause or is shifted to the embedded clause together with **tea**. Previously, it was observed that the dative was optional and therefore did not *trigger* reanalysis when left in the high clause (as in Kamide's result), the question here is whether the dative would be shifted once reanalysis is initiated by independent reasons (i.e., the accusative NP requirement). In order to explore this issue further, an off-line experiment is reported in the following section.

1.6 Experiment III — a non-minimal reanalysis

As observed previously, given that reanalysis occurs in Example (14a) in order to shift the accusative NP **tea** to the low clause, then a question remains as to whether the dative **manager** is displaced together with **tea** or stays in the high clause. Those two scenarios are shown in Example (17), with the square brackets indicating the two potential beginnings of the embedded clause after reanalysis.

Example (17)

a. Shokuin-wa kakarichou-ni [ocha-o onnanohito-ga isoide dashita-to ...
   employee-Top manager-Dat tea-Acc woman-Nom hurry served-Comp

b. Shokuin-wa [kakarichou-ni ocha-o onnanohito-ga isoide dashita-to ...

The minimal change interpretation in this case is shown in Example (17a), in which only the accusative NP **tea** is shifted to the low clause, while the dative **manager** remains in the high clause together with **employee**. Therefore, this is the preferred construction according to the MCS (minimal change strategy). Note that the dative NP, being an optional argument (as the results in Kamide, 1997, suggest), can indeed remain in the high clause; in addition the complementizer **to** attached to **served** is an indicator that the main verb is likely to be a report verb, therefore indicating that **manager** can indeed be part of the main clause as the goal for the main verb.

However, MaxG as repeated below, would predict that Example (17b) would be the outcome of reanalysis, as more constraints are satisfied in this interpretation (i.e., the requirement of associating the dative NP **manager** with a verb is satisfied immediately).

Maximal grammaticality (MaxG): once triggered, reanalysis attempts to optimally satisfy the grammatical constraints at each step.

In order to test their preferences after reanalysis takes place, native speakers of Japanese were given an off-line survey in which they rated whether the dative NP was more likely to be attached to the low or the high verb in sentences like Example (14a).

1.6.1 Method

Participants

Twenty-four participants, who did not participate in the on-line experiment, answered a questionnaire. They were all native speakers of Japanese and residents in the Kansai area of Japan.

Materials

Example (14a) is repeated below as Example (18a) with new adjectives and adverbs. And Example (18b) was used as its control. The items used in this experiment were the same as the ones used in Experiment II, with adjectives and adverbs added in the present case, and the subject in the main clause was marked as nominative rather than topic. Appendix 1-D contains the complete list of items used.

Example (18)

a.
Ofisude jimina shokuin-ga kakarichoo-ni shibui ocha-o onnanohito-ga dashita-to shinsetsuni shiraseta
office-at plain employee-Nom manager-Dat sour tea-Acc woman-Nom served-Comp politely said

"At the office, the plain employee politely said (to the manager) that the woman served sour tea (to the manager).

b.
Ofisude jimina shokuin-ga kakarichoo-ni onnanohito-ga shibui ocha-o dashita-to shinsetsuni shiraseta
office-at plain employee-Nom manager-Dat woman-Nom sour tea-Acc served-Comp politely said

"At the office, the plain employee politely said (to the manager) that the woman served sour tea (to the manager).

Both Examples (18a) and (18b) are ambiguous in that the dative **manager** can be attached to **served** or **said**. In both sentences, the nominative NP **woman** is initially taken to be

the beginning of the embedded clause according to the LBA. The difference between the two sentences is in the position of the accusative NP **sour tea**: before **woman** in (a) and after **woman** in (b). Therefore, (a) requires reanalysis at the verb **served** as attested in Experiment II. There is no reanalysis in (b) because the dative NP **manager** is optional and can be left in the main clause, whereas **tea** is interpreted as being part of the embedded clause from the start because of its position after the nominative NP **woman**.

If the reanalysis process in Example (18a) does not shift the dative **manager** to the low clause (as predicted by the MCS), then the attachment preference for that NP should be the same in both sentences. However, if MaxG is correct and reanalysis does displace **manager** together with **tea**, then the preference to attach **manager** to **served** should be stronger in (a) than in (b). Because both sentences are globally ambiguous, and both low and high attachments are grammatical, we should not expect (a) to show an absolute preference for the low attachment, but only a relative bias compared to the control sentence.

Procedure

There were a total of four conditions in this experiment, of which only two are being reported as the other two were testing an unrelated hypothesis by varying the case markers on the NPs within a RC.

Twenty-four items were presented in a Latin Square design together with another 36 unrelated items in pseudo-random order. First, participants rated how hard it was to understand each sentence by choosing a number on a difficulty scale from 1 to 7.

Next, participants were asked to choose between two paraphrases of the sentence just read. One phrase had the dative NP as the object of the low verb and the other phrase had the same dative NP as the object of the high verb. Participants chose a number on a scale from 1 to 7, each extreme representing the participant's preference for one interpretation over the other. For half of the items, the low attachment condition was presented next to the number "1" and, for the other half, next to the number "7". For the analysis below, the numbers were converted so that "1" always stands for the low attachment preference and "7" for the high attachment preference.

1.6.2 Results

Example (18a) was marginally more difficult than Example (18b) in the analysis by subject ($F_1(1,23) = 3.36$, $p = 0.08$), but the difference was not significant in the analysis by items ($F_2(1,23) = 2.50$, $p = 0.127$).

As predicted by Maximal Grammaticality, the dative NP was more strongly attached to the low verb in Example (18a) than in Example (18b) as can be seen in Figure 1.7. This difference was significant both by subjects ($F_1(1,23) = 12.08$, $p < 0.01$) as well as by items ($F_2(1,23) = 18.4$, $p < 0.001$).

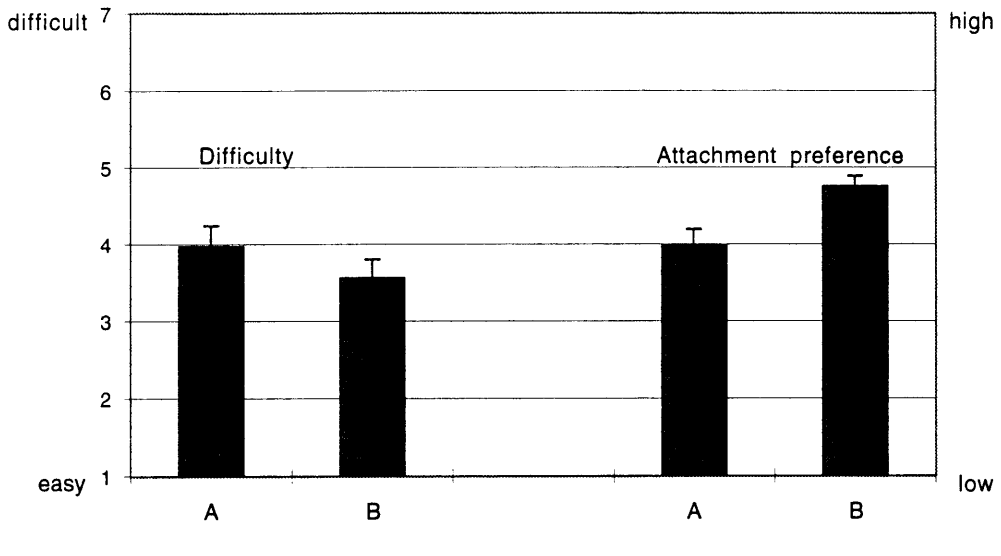

Figure 1.7: Experiment III: difficulty and attachment preference.

1.6.3 Discussion

The present result supports MaxG/CDC as it indicates that grammaticality is a sufficient condition for a modification to be carried out during reanalysis, therefore determining the interpretation to be pursued. Contrary to what the MCS states, minimizing change (and possibly minimizing difficulty) does not seem to be a factor guiding re-interpretation.

The result suggests that the dative NP is likely to be lowered with the accusative NP during reanalysis in Example (18a), thus arguing against the view that the dative NP remains

in the high clause because the parser wants to minimize change. Instead, during reanalysis, the parser satisfies even an optional requirement (the attachment of the dative object to a optionally ditransitive verb) which on its own would not be enough to trigger reanalysis. This view of reanalysis as dictated in part by the disambiguating segment (the embedded verb in the present case) agrees in spirit with the proposal in Fodor & A. Inoue (1994) that the reanalysis signal is important during this process. (See also Frazier, 1998, where minimal revisions is re-stated so as to take into account information in the reanalysis signal.) However, according to the present results, the parser matches as best as it can the grammatical requirements (the subcategorization frame of the verb) and the resources available (the NPs tea and manager which can be interpreted as its arguments).

An interesting question that remains is why accusative (o-marked) NPs trigger reanalysis, whereas dative (ni-marked) NPs on their own do not. The next subsection suggests that this optionality of datives is related to the subcategorization requirements of verbs and examines a classification of arguments reported in Sadakane & Koizumi (1995), in which some types of ni-marked NPs are more strongly subcategorized than others and as a consequence may be more strongly required by a verb during reanalysis. A more refined analysis of Experiment II will be presented, in which the slow-down during reanalysis correlates with how strongly a ni-marked NP is subcategorized by the embedded verb. Reanalysis then can be characterized as a process finely tuned with the argument structure of the verbs present in the construction as suggested in MaxG.

Optionality of ni-marked NPs

One crucial assumption in the last two experiments has been the optionality of ni-marked, in contrast to o-marked, NPs. The purpose of this section is to investigate the nature of this distinction between dative and accusative NPs based on semantic factors or more precisely on the subcategorization requirements of verbs. A more fine-grained, though partial, analysis will be reported suggesting that the reanalysis observed in Experiment II is influenced by subtle aspects of the subcategorization frame of the embedded verb and that the ni versus o distinction is an instance of this phenomenon.

Although all occurrences of ni have been referred so far as datives, this particle has in

fact two distinct uses in Japanese: it can function as a case marker or as a postposition. This is particularly relevant considering that in some situations case marked NPs and postpositional phrases in Japanese share properties with arguments and adjuncts respectively (Miyagawa, 1989, p. 34). Based on an extensive survey of the various environments in which ni can occur, Sadakane & Koizumi (1995) concluded that the function of this particle correlates with the degree of *affectedness* (as in Jaeggli, 1986) of the NP. "That is, the case marker ni is attached to an NP whose referent is relatively more affected in the action denoted by the verb (predicate/sentence), and the postposition ni is attached to an NP whose referent is less affected." (Sadakane & Koizumi, 1995, pp. 18-19) They also note that "Although dative NPs tend to be more affected than NPs in a PP, they tend to be less affected than accusative NP objects." (p. 21)

In short, Sadakane and Koizumi propose a hierarchy in which NPs with an accusative marker (as in Example (19a) below) are the most affected, followed by NPs with the dative case marker ni (as in Example (19b)), and finally the least affected are NPs with the postposition ni (as in Examples (19c) and (19d)). They also propose another category for ambiguous ni-marked NPs whose affectedness can vary depending on the interpretation given to the goal (Example (19e)).

Example (19) (Examples from Sadakane & Koizumi, 1995.)
a. Accusative case marker o (highly affected)
John-ga Tom-o koroshita.
John-Nom TomAcc killed
"John killed Tom."

b. Dative case marker ni (affected) — goal indirect object
Emi-wa Mika-ni bara-no hanataba-o ageta.
Emi-Top Mika-NI rose-Gen bouquet-Acc gave
"Emi gave a bouquet of roses to Mika."

c. Postposition ni (least affected) — benefactive
Emi-wa oi-ni omocha-o katta
Emi-Top nephew-NI toy-Acc bought
"Emi bought a toy for her nephew."

d. Postposition ni (least affected) — from/by agent
Hokuto-wa ryoori-no shikata-o hahaoya-ni naratta
Hokuto-Top cooking-Gen way-Acc mother-NI learned
"Hokuto learned how to cook from his mother."

e. Dative of direction with a transitive verb (ambiguous between case marker and postposition)
Kanta-wa Mika-ni hanataba-o okutta
Kanta-Top Mika-NI bouquet-Acc sent
"Hokuto sent a bouquet to Mika."

Assume that the affectedness of an NP correlates with its obligatoriness as the object of a verb during the processing of a clause. Thus, accusative NPs being more affected are also more strongly required by a verb during parsing than NPs marked with ni in general. Similarly, considering the relative affectedness of different types of ni-marked NPs, it should be the case that ni-case-marked NPs are more required during parsing than NPs with the ni-postposition (or ni PPs for short). In this case, the distinction assumed in the processing of o versus ni in Experiments II and III, rather than an arbitrary dichotomy, may instead be one instance of a more general phenomenon, namely, the subcategorization frame of a verb determining the types of arguments that are more crucial to the processing of the clause.

Following the classification and tests in Sadakane & Koizumi (1995), the stimuli used in Experiments II were divided in three categories according to the use of the particle ni: ni-case-marked NPs (Type I), ni PPs (Type II) and ambiguous. There were eight items of Type I, eight of Type II, and the rest were ambiguous. In the following, the ambiguous items will not be considered.

In Experiment II, a slow-down was detected in the test sentence at the embedded verb, which was caused by reanalysis triggered to satisfy the accusative NP requirement. See Example (14a), repeated below as Example (20).

Example (20)

Shokuin-wa kakarichou-ni ocha-o onnanohito-ga isoide dashita-to shiraseta.
employee-Top manager-Dat tea-Acc woman-Nom hurry served-Comp said

"The employee said (to the manager) that the woman served tea hurriedly (to the manager)."

Assume that the lowering of the ni-marked NP during reanalysis in Example (20) is probabilistic and depends on the strength with which the embedded verb **served** requires that NP to be present. The assumption here is that the linguistic behaviour is probabilistic (therefore speakers do not always make the attachment in the same manner even with the same sentence) and it is modulated by a non-probabilistic constraint stemming from the meaning of the verb. In this way, the more strongly the NP is subcategorized for (or is affected) by the embedded verb, the more likely it will be shifted from the high to the low clause. In this scenario, a ni-marked NP is more likely to be shifted in the stimuli of Type I than in Type II. If, as observed in Experiment I, the number of NPs shifted correlates with slower reading times, then we should expect a more marked slow-down for the Type I items in the self-paced reading data of Experiment II. In particular, the slow-down in the test sentences (condition A) should be more pronounced with items of Type I than Type II, but no such difference should be detectable in the unambiguous controls (condition B). This is in fact what the reading times for the embedded verb suggest. Figure 1.8 presents the mean residual reading times at the embedded verb.

Since this was not the original intent of the experiment, most participants did not see all the conditions in this 2×2 design, and the analysis by subjects could not be carried out. In the analysis by items, the interaction between ambiguity and type of ni is marginally significant ($F_2(1,14) = 3.375$, $p = 0.088$); and, for the test sentences (condition A), the case-marker condition is marginally slower than the postposition ($F_2(1,14) = 4.296$; $p = 0.057$). Note that the previous (main effect) result that ni NPs in general are being shifted still holds, as the overall slower reading times in condition (A) suggest, but the new analysis

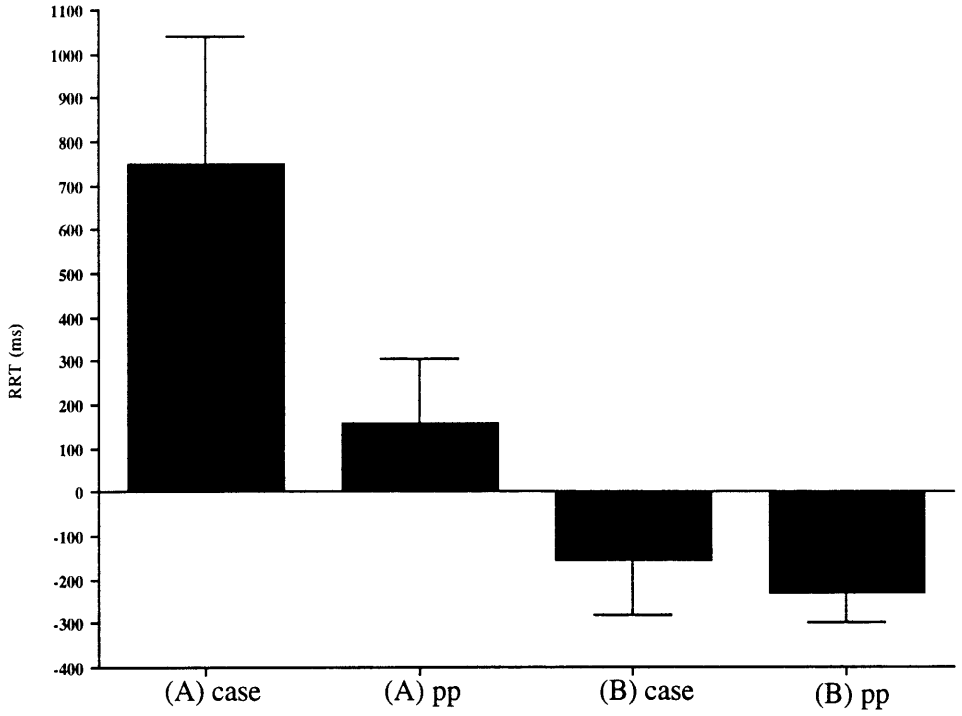

Figure 1.8: Experiment II and ni classification: mean residual reading times and standard errors for region 6 (the embedded verb). Condition (A) corresponds to the ambiguous sentences and (B) to the unambiguous control sentences.

here indicates that this may be stronger with the case markers than with the posposition marked NPs.

Given the analyses in Experiments II and III alone, it could be argued that the phenomenon observed has its origin in the structure of syntactic trees in that an accusative NP cannot be lowered alone, and the whole VP shell containing the ni NP and the accusative NP has to be shifted entirely. But with the distinction advocated in this new analysis between the two types of nis, which is dependent on the verb's subcategorization frame, such a structural explanation becomes less likely.

The results in this subsection should be taken with caution, as the analyses above are incomplete and only marginally significant. However, if supported by future work, these results would further support the hypothesis of reanalysis as a process guided by grammatical requirements.

1.7 Conclusion

Grammaticality has often been taken for granted in sentence reanalysis as many of the constructions studied by researchers could be explained with some type of minimal change strategy (Fodor & A. Inoue, 1994; Frazier, 1994). This is the case with NPs displaced in Japanese simple clause/RC ambiguities (Mazuka & Itoh, 1995), in which MaxG (maximal grammaticality) and the MCS (minimal change strategy) make the same predictions. But it was suggested here that MaxG and the CDC (constraint driven change) are determining the preference rather than the MCS: the parser will execute only those changes that lead to a more grammatical representation. Experiments II and III support this reasoning by showing that the human parser will make more changes if more grammatical requirements can be satisfied that way.

This view of reanalysis agrees in spirit with the proposal in Fodor & A. Inoue (1994) that the information in the reanalysis signal is important during this process. However, given the result in Experiment I, the conclusion here diverges from Fodor and Inoue in that the clarity of the disambiguating segment cannot be the only source of difficulty during reanalysis, rather reanalysis seems to be guided by grammatical constraints, and difficulty is determined by the process of transforming the old mental representation into a new one compatible with the disambiguating segment. Such a process may be harder to accomplish if the reanalysis signal is unclear, but also if the constraints involved require more changes to be made.

Appendix 1-A.

In Experiment I, the subject of the main clause was topicalized in order to avoid two NPs with nominative marker for the following reason. In a previous version of this experiment, the subject of the main clause was marked with nominative case, rather than topic; therefore, all the control sentences had two NPs marked as nominative (Examples (21b) and (21c) below, which correspond to Examples (4d) and (4e) respectively) and they were read as slowly as the test sentences at the head of the RC (region 7).

Example (21)

Regions for the self-reading presentation:

1	2	3	4	5	6	7	8	9

a. Obasan-ga yoboyobo-no toshiyori-o [$_{RC}$ guuzen-ni kousaten-de mita] takushii-ni isoide noseta.
woman-Nom feeble old-man-Acc by chance intersect-Loc saw taxi-Dat hurry put
"The woman put the feeble old-man in a hurry in the taxi that she saw at the intersection by chance."

b. Obasan-ga yoboyobo-no toshiyori-o [$_{RC}$ gakusei-ga kousaten-de mita] takushii-ni isoide noseta.
woman-Nom feeble old-man-Acc student-Nom intersect-Loc saw taxi-Dat hurry put
"The woman put the feeble old-man in a hurry in the taxi that the student saw at the intersection."

c. Yoboyobo-no toshiyori-o obasan-ga [$_{RC}$ gakusei-ga kousaten-de mita] takushii-ni isoide noseta.
feeble old-man-Acc woman-Nom student-Nom intersect-Loc saw taxi-Dat hurry put
"The woman put the feeble old-man in a hurry in the taxi that the student saw at the intersection."

Twenty-three native speakers of Japanese participated in this self-paced reading experiment. The items were exactly the same as in Experiment I, except for the topic marker. The same setup was used with 52 fillers.

See Figure 1.9 for all residual reading times. At word seven (the RC head taxi), the conditions do not differ significantly (Fs < 1). The comprehension performances, given in Table 1-A, are not significantly different ($F_1(2,44) = 2.48$, $p = 0.095$; $F_2(2,58) < 1$).

Condition	A	B	C
Correct responses (%)	69.6	70.3	78.3

Table 1.3: Percent correct for the double nominative version of Experiment I

The lack of significant difference in region 7 of the present version of the experiment

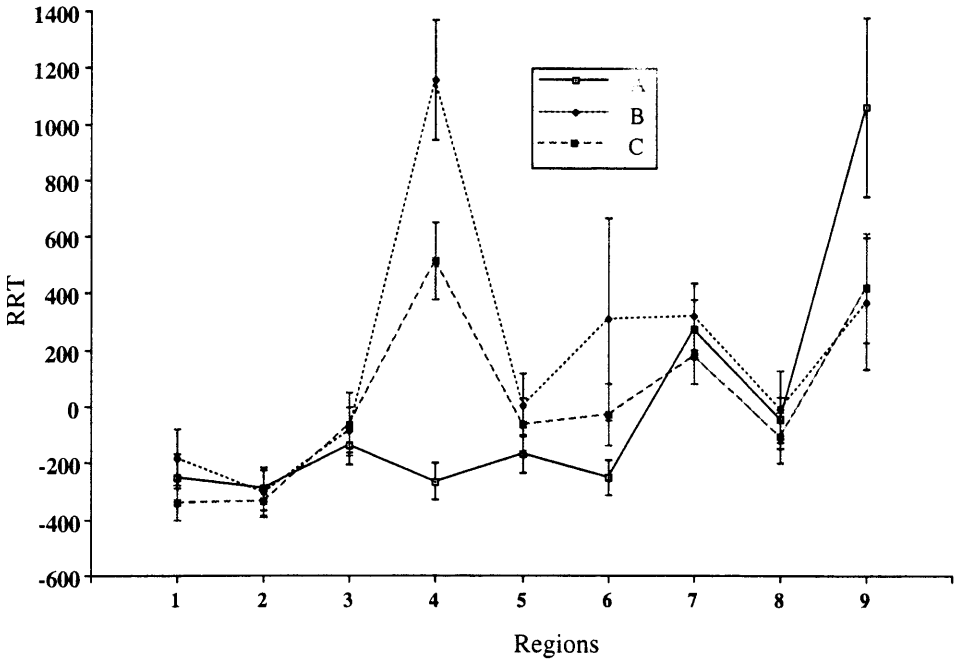

Figure 1.9: Double nominative controls: Residual Reading Times for conditions (a), (b) and (c).

suggests that the double nominative NPs may have been so disruptive that the slow-down persevered in the following regions of the control sentences. This is supported by the fact that after their experimental session was over, several participants complained about sentences with two nominative NPs (i.e., the control sentences) as being confusing, because they could not decide which nominative NP was the "main topic" of the sentence.

The following considers some possible causes for the difficulty to process double nominative NPs in a self-paced reading presentation. Masakatsu Inoue (personal communication), in comparing eye-tracking to self-paced reading data, suggests that Japanese speakers seem to memorize the words being presented in the latter methodology, hence, overloading short-term memory. On the one hand, then, short-term memory may be overloaded because of the style of sentence presentation. On the other hand, there is the difficulty in processing the nominative NPs, which may prevent the recoding of the items stored in short-term memory into fewer chunks (Miller, 1963; Uehara, 1997, for an off-line study on the processing of

sequences of nominative NPs). But it is almost certain that the problem is not related to confusability at the phonological level. That is, given two NPs with the same case marker, it would be conceivable that readers have difficulty differentiating them during retrieval as the parsing of the sentence proceeds (see the *phonological similarity effect* in Baddeley, 1990). However, this phonological confusability hypothesis is contradicted by two facts. First, the phonological confusability should only affect processing at later stages, when the parser attempts to retrieve the NPs, instead the slow-down occurs immediately at the second nominative NP. Moreover, two accusative NPs should be as problematic as two nominative NPs according to this hypothesis; however, in the following experiment, control sentences with two accusative NPs were used, and no apparent disruption was detected.

Example (22)

Regions for the self-paced reading presentation:
1 2 3 4 5 6 7 8

a. Ofisu-de shokuin-ga kakarichoo-ni ocha-o dashita josei-o teinei-ni shoukai-shita.
office-Loc employee-Nom manager-Dat tea-Acc served woman-Acc politely introduced
"At the office an employee politely introduced (to the manager) the woman who served tea (to the manager)."

b. Ofisu-de kakarichoo-o shokuin-ga ocha-o dashita josei-ni teinei-ni shoukai-shita.
"At the office an employee politely introduced the manager to the woman who served tea."

c. Ofisu-de shokuin-ga kakarichoo-o ocha-o dashita josei-ni teinei-ni shoukai-shita.
"At the office an employee politely introduced the manager to the woman who served tea."

Example (22a) is initially processed as a single clause sentence, then reanalysis takes place at **woman** (this is the first point where it is clear that the sentence contains more than one clause) in order to create the RC. The three sentences differ in the position of the word **manager** and in the underlined case markers. The two accusative NPs indicate that Examples (22b) and (22c) have more than one clause (the Double-o constraint in Japanese forbids more than one accusative NP in a single clause; see Tsujimura, 1996, and references therein), thus, no reanalysis should occur at **woman**.

Thirty-seven native speakers of Japanese living in the Boston area participated in the study. The items were partially based on sentences from Yamashita (1994). The results at

the word woman were as follows. Examples (22b) and (22c) were both significantly faster than Example (22a) by subjects and by items ($p < 0.05$). See Figure 1.10 for all residual reading times.

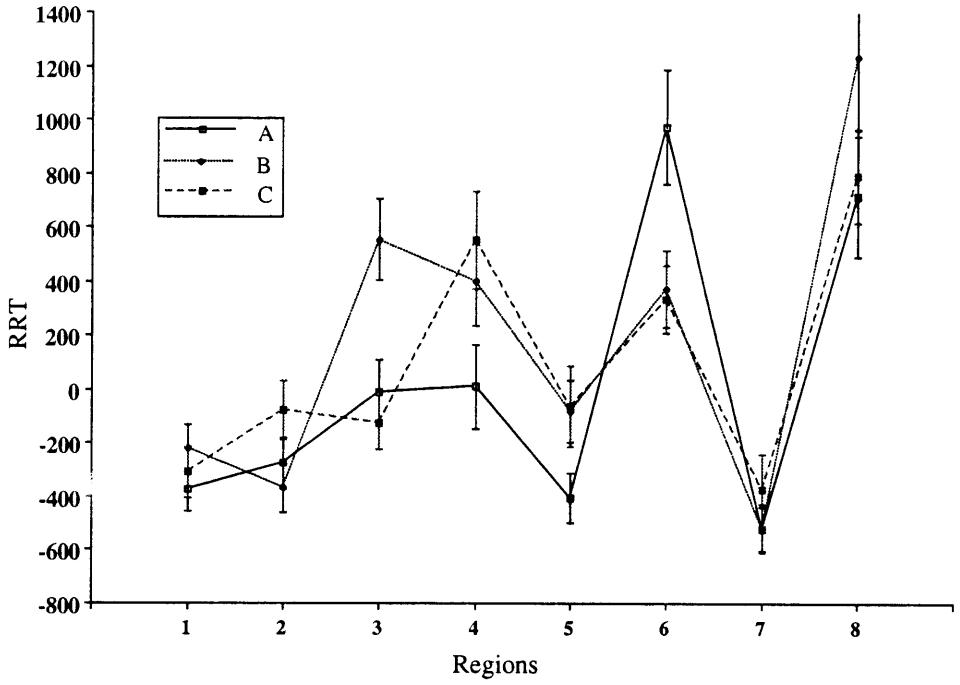

Figure 1.10: Double accusative controls: Residual Reading Times for conditions (a), (b) and (c).

The fact that double accusatives do not disrupt processing contrasts with the null result obtained in the previous experiment with double nominatives. One possible explanation is that, very often, the closest translation for "Mary-ga..." is "It's Mary that..." (see Kuno, 1973, for the exhaustive interpretation of ga). Hence, with multiple nominative NPs, it is unclear around which entity the clause is going to revolve. Moreover, in on-line processing, nominative markers seem particularly important as they may be used as cues for the beginning of a new clause.

Appendix 1-B.

The following is the list of stimuli used in Experiment I and in the double nominative version reported in Appendix 1-A. Sentences 1, 18, 23, 25, 29 have RC heads (Region 7) that could be interpreted as the subject of the RC in conditions C, D and E, and were eliminated from the inanimate RC head analysis reported in the discussion of Experiment I.

1a. おばあさんは よぼよぼの 年寄りを 偶然に 交差点で 見た 女の子に 急いで 声をかけた。
1b. おばあさんは よぼよぼの 年寄りが 偶然に 交差点で 見た 女の子に 急いで 声をかけた。
1c. おばあさんは よぼよぼの 年寄りを 偶然に 交差点で 見た タクシーに 急いで 乗せた。
1d. おばあさんは よぼよぼの 年寄りを 学生が 交差点で 見た タクシーに 急いで 乗せた。
1e. よぼよぼの 年寄りを おばあさんは 学生が 交差点で 見た タクシーに 急いで 乗せた。

2a. 店員は 怪しい 男を ちらっと 通りで 見た 女性に その場で お礼を言った。
2b. 店員は 怪しい 男が ちらっと 通りで 見た 女性に その場で お礼を言った。
2c. 店員は 怪しい 男を ちらっと 通りで 見た 交番に その場で 突き出した。
2d. 店員は 怪しい 男を 運転手が 通りで 見た 交番に その場で 突き出した。
2e. 怪しい 男を 店員は 運転手が 通りで 見た 交番に その場で 突き出した。

3a. 店員さんは 酔っ払いの おじさんを じっと パチンコ屋で 狙っていた ホームレスに 怒って 話しをした。
3b. 店員さんは 酔っ払いの おじさんが じっと パチンコ屋で 狙っていた ホームレスに 怒って 話しをした。
3c. 店員さんは 酔っ払いの おじさんを じっと パチンコ屋で 狙っていた パチンコ台に 怒って 押し付けた。
3d. 店員さんは 酔っ払いの おじさんを 乞食が パチンコ屋で 狙っていた パチンコ台に 怒って 押し付けた。
3e. 酔っ払いの おじさんを 店員さんは 乞食が パチンコ屋で 狙っていた パチンコ台に 怒って 押し付けた。

4a. 公務員は 太った 政治家を 静かに 長いこと 見つめていた 係員に 確かに 悪口を言った。
4b. 公務員は 太った 政治家が 静かに 長いこと 見つめていた 係員に 確かに 悪口を言った。
4c. 公務員は 太った 政治家を 静かに 長いこと 見つめていた 椅子に 確かに すわらせた。
4d. 公務員は 太った 政治家を 大臣が 長いこと 見つめていた 椅子に 確かに すわらせた。
4e. 太った 政治家を 公務員は 大臣が 長いこと 見つめていた 椅子に 確かに すわらせた。

5a. 心臓病学者は 年寄りの 病人を 突然に 廊下で 見た 看護婦に 丁寧に 注意した。
5b. 心臓病学者は 年寄りの 病人が 突然に 廊下で 見た 看護婦に 丁寧に 注意した。
5c. 心臓病学者は 年寄りの 病人を 突然に 廊下で 見た 車椅子に 丁寧に 乗せた。
5d. 心臓病学者は 年寄りの 病人を 助手が 廊下で 見た 車椅子に 丁寧に 乗せた。
5e. 年寄りの 病人を 心臓病学者は 助手が 廊下で 見た 車椅子に 丁寧に 乗せた。

6a. 警察官は やくざの 幹部を 内緒で 空港で 探していた 女の人に うまく 尋問した。
6b. 警察官は やくざの 幹部が 内緒で 空港で 探していた 女の人に うまく 尋問した。
6c. 警察官は やくざの 幹部を 内緒で 空港で 探していた 飛行機に うまく 閉じ込めた。
6d. 警察官は やくざの 幹部を 探偵が 空港で 探していた 飛行機に うまく 閉じ込めた。
6e. やくざの 幹部を 警察官は 探偵が 空港で 探していた 飛行機に うまく 閉じ込めた。

7a. 男の子は 黒い 犬を どきどきと いつも 怖がっていた おばあさんに とうとう 話しかけた。
7b. 男の子は 黒い 犬が どきどきと いつも 怖がっていた おばあさんに とうとう 話しかけた。
7c. 男の子は 黒い 犬を どきどきと いつも 怖がっていた お化け屋敷に とうとう 入らせた。
7d. 男の子は 黒い 犬を おばさんが いつも 怖がっていた お化け屋敷に とうとう 入らせた。
7e. 黒い 犬を 男の子は おばさんが いつも 怖がっていた お化け屋敷に とうとう 入らせた。

8a. 看護婦は 背の低い 患者さんを 一生懸命 医務室で 探していた 学生に 急いで 呼びかけた。
8b. 看護婦は 背の低い 患者さんが 一生懸命 医務室で 探していた 学生に 急いで 呼びかけた。
8c. 看護婦は 背の低い 患者さんを 一生懸命 医務室で 探していた 名簿に 急いで 入れた。
8d. 看護婦は 背の低い 患者さんを 事務員が 医務室で 探していた 名簿に 急いで 入れた。
8e. 背の低い 患者さんを 看護婦は 事務員が 医務室で 探していた 名簿に 急いで 入れた。

9a. 女子大生は 内気な 会社員を こっそり 奈良で 訪ねた 踊子に 突然 はち合わせた。
9b. 女子大生は 内気な 会社員が こっそり 奈良で 訪ねた 踊子に 突然 はち合わせた。
9c. 女子大生は 内気な 会社員を こっそり 奈良で 訪ねた お寺に 突然 行かせた。
9d. 女子大生は 内気な 会社員を いとこが 奈良で 訪ねた お寺に 突然 行かせた。
9e. 内気な 会社員を 女子大生は いとこが 奈良で 訪ねた お寺に 突然 行かせた。

10a. お兄さんは 出来の悪い 弟を 必死で 図書館で 探していた 家庭教師に すぐに 謝った。
10b. お兄さんは 出来の悪い 弟が 必死で 図書館で 探していた 家庭教師に すぐに 謝った。
10c. お兄さんは 出来の悪い 弟を 必死で 図書館で 探していた 勉強部屋に すぐに 閉じ込めた。
10d. お兄さんは 出来の悪い 弟を 後輩が 図書館で 探していた 勉強部屋に すぐに 閉じ込めた。
10e. 出来の悪い 弟を お兄さんは 後輩が 図書館で 探していた 勉強部屋に すぐに 閉じ込めた。

11a. 老人は 酔っ払いの 暴走族を 偶然に 高速道路で 見た 学生に 頭から 衝突された。
11b. 老人は 酔っ払いの 暴走族が 偶然に 高速道路で 見た 学生に 頭から 衝突された。
11c. 老人は 酔っ払いの 暴走族を 偶然に 高速道路で 見た 電柱に 頭から 衝突させてしまった。
11d. 老人は 酔っ払いの 暴走族を ひ孫が 高速道路で 見た 電柱に 頭から 衝突させてしまった。
11e. 酔っ払いの 暴走族を 老人は ひ孫が 高速道路で 見た 電柱に 頭から 衝突させてしまった。

12a. 社長は 貧乏な お客さんを わざと 長期間 無視していた 社員に さりげなく 注意した。
12b. 社長は 貧乏な お客さんが わざと 長期間 無視していた 社員に さりげなく 注意した。
12c. 社長は 貧乏な お客さんを わざと 長期間 無視していた 取引に さりげなく 誘いました。
12d. 社長は 貧乏な お客さんを 社員が 長期間 無視していた 取引に さりげなく 誘いました。
12e. 貧乏な お客さんを 社長は 社員が 長期間 無視していた 取引に さりげなく 誘いました。

13a. 係長は 若い お客を こっそり 旅行会社で 気に入っていた ガイドに 喜んで 案内させた。
13b. 係長は 若い お客が こっそり 旅行会社で 気に入っていた ガイドに 喜んで 案内させた。
13c. 係長は 若い お客を こっそり 旅行会社で 気に入っていた ツアーに 喜んで 参加させた。
13d. 係長は 若い お客を ガイドが 旅行会社で 気に入っていた ツアーに 喜んで 参加させた。
13e. 若い お客を 係長は ガイドが 旅行会社で 気に入っていた ツアーに 喜んで 参加させた。

14a. エージェントは 新人 歌手を 一目で テレビ局で 気に入った カメラマンに 何回も 話しをした。
14b. エージェントは 新人 歌手が 一目で テレビ局で 気に入った カメラマンに 何回も 話しをした。
14c. エージェントは 新人 歌手を 一目で テレビ局で 気に入った テレビ番組に 何回も 出演させた。
14d. エージェントは 新人 歌手を 友人が テレビ局で 気に入った テレビ番組に 何回も 出演させた。
14e. 新人 歌手を エージェントは 友人が テレビ局で 気に入った テレビ番組に 何回も 出演させた。

15a. 写真家は 内気な モデルを 内緒で 一目で 気に入った 会社員に 親切に けちをつけた。
15b. 写真家は 内気な モデルが 内緒で 一目で 気に入った 会社員に 親切に けちをつけた。
15c. 写真家は 内気な モデルを 内緒で 一目で 気に入った 喫茶店に 親切に 誘った。
15d. 写真家は 内気な モデルを 社員が 一目で 気に入った 喫茶店に 親切に 誘った。
15e. 内気な モデルを 写真家は 社員が 一目で 気に入った 喫茶店に 親切に 誘った。

16a. 美容師は お金持ちの お客を ぼんやり 鏡で 見ていた アシスタントに 素早く カットをやらせた。
16b. 美容師は お金持ちの お客が ぼんやり 鏡で 見ていた アシスタントに 素早く カットをやらせた。
16c. 美容師は お金持ちの お客を ぼんやり 鏡で 見ていた シャンプー台に 素早く 連れて行った。
16d. 美容師は お金持ちの お客を 副店長が 鏡で 見ていた シャンプー台に 素早く 連れて行った。
16e. お金持ちの お客を 美容師は 副店長が 鏡で 見ていた シャンプー台に 素早く 連れて行った。

17a. 教授は 内気な 留学生を 気長に コンピューターで 探していた 大学院生に 親切に 電子メールを送った。
17b. 教授は 内気な 留学生が 気長に コンピューターで 探していた 大学院生に 親切に 電子メールを送った。
17c. 教授は 内気な 留学生を 気長に コンピューターで 探していた アパートに 親切に 住まわせた。
17d. 教授は 内気な 留学生を 秘書が コンピューターで 探していた アパートに 親切に 住まわせた。
17e. 内気な 留学生を 教授は 秘書が コンピューターで 探していた アパートに 親切に 住まわせた。

18a. 大学生たちは せわしい 小学生を 気長に 駅前で 待っていた 友達に 慌てて 道を聞いた。
18b. 大学生たちは せわしい 小学生が 気長に 駅前で 待っていた 友達に 慌てて 道を聞いた。
18c. 大学生たちは せわしい 小学生を 気長に 駅前で 待っていた バスに 慌てて 乗らせた。
18d. 大学生たちは せわしい 小学生を 先生が 駅前で 待っていた バスに 慌てて 乗らせた。
18e. せわしい 小学生を 大学生たちは 先生が 駅前で 待っていた バスに 慌てて 乗らせた。

19a. 新聞記者は 素人の 役者を 偶然に テレビで 見た 監督に 何回も 質問をした。
19b. 新聞記者は 素人の 役者が 偶然に テレビで 見た 監督に 何回も 質問をした。
19c. 新聞記者は 素人の 役者を 偶然に テレビで 見た 劇場に 何回も 連れて行った。
19d. 新聞記者は 素人の 役者を 友人が テレビで 見た 劇場に 何回も 連れて行った。
19e. 素人の 役者を 新聞記者は 友人が テレビで 見た 劇場に 何回も 連れて行った。

20a. ガイドさんは にぎやかな 観光客を 上手に パノラマで 写した 青年達に 約束通りに お金をあげた。
20b. ガイドさんは にぎやかな 観光客が 上手に パノラマで 写した 青年達に 約束通りに お金をあげた。
20c. ガイドさんは にぎやかな 観光客を 上手に パノラマで 写した 富士山に 約束通りに 登らせた。
20d. ガイドさんは にぎやかな 観光客を 青年が パノラマで 写した 富士山に 約束通りに 登らせた。
20e. にぎやかな 観光客を ガイドさんは 青年が パノラマで 写した 富士山に 約束通りに 登らせた。

21a. ボディガードは アイドル 歌手を たまたま 楽屋で 見つけた ファンの子に すばやく キスをした。
21b. ボディガードは アイドル 歌手が たまたま 楽屋で 見つけた ファンの子に すばやく キスをした。
21c. ボディガードは アイドル 歌手を たまたま 楽屋で 見つけた 衣装だんすに すばやく 隠した。
21d. ボディガードは アイドル 歌手を 知合いが 楽屋で 見つけた 衣装だんすに すばやく 隠した。
21e. アイドル 歌手を ボディガードは 知合いが 楽屋で 見つけた 衣装だんすに すばやく 隠した。

22a. 課長は しつこい 社員を できるだけ いつも 避けていた 同僚に 一緒に 外周りをさせた。
22b. 課長は しつこい 社員が できるだけ いつも 避けていた 同僚に 一緒に 外周りをさせた。
22c. 課長は しつこい 社員を できるだけ いつも 避けていた 出張に 一緒に 行かせた。
22d. 課長は しつこい 社員を 新入社員が いつも 避けていた 出張に 一緒に 行かせた。
22e. しつこい 社員を 課長は 新入社員が いつも 避けていた 出張に 一緒に 行かせた。

23a. おじいさんは 可愛い 小学生を すんなりと 自転車で 追い越した 先生に 遠慮なく お願いを頼んだ。
23b. おじいさんは 可愛い 小学生が すんなりと 自転車で 追い越した 先生に 遠慮なく お願いを頼んだ。
23c. おじいさんは 可愛い 小学生を すんなりと 自転車で 追い越した バスに 遠慮なく 乗せてあげた。
23d. おじいさんは 可愛い 小学生を 青年たちが 自転車で 追い越した バスに 遠慮なく 乗せてあげた。
23e. 可愛い 小学生を おじいさんは 青年たちが 自転車で 追い越した バスに 遠慮なく 乗せてあげた。

24a. 老人は 疲れていた おばさんを つい 普通電車の中で 押し倒した おとこの人に 少し 怒った。
24b. 老人は 疲れていた おばさんが つい 普通電車の中で 押し倒した おとこの人に 少し 怒った。
24c. 老人は 疲れていた おばさんを つい 普通電車の中で 押し倒した 段ボール箱に 少し 座らせた。
24d. 老人は 疲れていた おばさんを 孫が 普通電車の中で 押し倒した 段ボール箱に 少し 座らせた。
24e. 疲れていた おばさんを 老人は 孫が 普通電車の中で 押し倒した 段ボール箱に 少し 座らせた。

25a. お父さんは 眠たそうな 子供を 一生懸命に 急行列車の中で 支えていた 老人に 丁寧に 話しかけた。
25b. お父さんは 眠たそうな 子供が 一生懸命に 急行列車の中で 支えていた 老人に 丁寧に 話しかけた。
25c. お父さんは 眠たそうな 子供を 一生懸命に 急行列車の中で 支えていた 荷物に 丁寧に 寄りかからせた。
25d. お父さんは 眠たそうな 子供を お母さんが 急行列車の中で 支えていた 荷物に 丁寧に 寄りかからせた。
25e. 眠たそうな 子供を お父さんは お母さんが 急行列車の中で 支えていた 荷物に 丁寧に 寄りかからせた。

26a. 浪人は 痩せっぽちの 高校生を さんざん 運動場で 馬鹿にしていた コーチに しつこく 文句をいった。
26b. 浪人は 痩せっぽちの 高校生が さんざん 運動場で 馬鹿にしていた コーチに しつこく 文句をいった。
26c. 浪人は 痩せっぽちの 高校生を さんざん 運動場で 馬鹿にしていた ゲームに しつこく 誘った。
26d. 浪人は 痩せっぽちの 高校生を コーチが 運動場で 馬鹿にしていた ゲームに しつこく 誘った。
26e. 痩せっぽちの 高校生を 浪人は コーチが 運動場で 馬鹿にしていた ゲームに しつこく 誘った。

27a. 精神科医は 狂暴な 患者を ひどく リハビリテーションで 怖がっていた こどもに とうとう 声をかけた。
27b. 精神科医は 狂暴な 患者が ひどく リハビリテーションで 怖がっていた こどもに とうとう 声をかけた。
27c. 精神科医は 狂暴な 患者を ひどく リハビリテーションで 怖がっていた 特別室に とうとう 入れた。
27d. 精神科医は 狂暴な 患者を 同僚が リハビリテーションで 怖がっていた 特別室に とうとう 入れた。
27e. 狂暴な 患者を 精神科医は 同僚が リハビリテーションで 怖がっていた 特別室に とうとう 入れた。

28a. 家主は 貧しい 学生達を いじわるく 長い間 放っておいた 不動産屋に 急に 声をかけた。
28b. 家主は 貧しい 学生達が いじわるく 長い間 放っておいた 不動産屋に 急に 声をかけた。
28c. 家主は 貧しい 学生達を いじわるく 長い間 放っておいた アパートに 急に 引っ越しさせた。
28d. 家主は 貧しい 学生達を 不動産屋が 長い間 放っておいた アパートに 急に 引っ越しさせた。
28e. 貧しい 学生達を 家主は 不動産屋が 長い間 放っておいた アパートに 急に 引っ越しさせた。

29a. 運転手は 無邪気な 子供を やさしく 公園で なでていた 子守に そっと 道を聞いた。
29b. 運転手は 無邪気な 子供が やさしく 公園で なでていた 子守に そっと 道を聞いた。
29c. 運転手は 無邪気な 子供を やさしく 公園で なでていた りすに そっと 近づけさせた。
29d. 運転手は 無邪気な 子供を 高校生が 公園で なでていた りすに そっと 近づけさせた。
29e. 無邪気な 子供を 運転手は 高校生が 公園で なでていた りすに そっと 近づけさせた。

30a. 事務員は 鋭い インターンを ようやく 先月 探してきた 秘書に 即刻 連絡をした。
30b. 事務員は 鋭い インターンが ようやく 先月 探してきた 秘書に 即刻 連絡をした。
30c. 事務員は 鋭い インターンを ようやく 先月 探してきた 仕事に 即刻 つかせた。
30d. 事務員は 鋭い インターンを 副部長が 先月 探してきた 仕事に 即刻 つかせた。
30e. 鋭い インターンを 事務員は 副部長が 先月 探してきた 仕事に 即刻 つかせた。

Appendix 1-C.

The following is the list of stimuli used in Experiment II. These sentences were partly based on Yamashita (1994).

The ni marker in sentences 2, 4, 7, 8, 9, 14, 16 and 19 was classified as a case marker, whereas in sentences 3, 6, 10, 17, 20, 22, 23 and 25 it was classified as a postposition. The rest of the items were ambiguous and were not used in the analysis of different types of nis reported in the discussion section of Experiment III.

1a. 職員は 係長に お茶を 女の人が 急いで 出したと 知らせた。
1b. 職員は 女の人が 係長に お茶を 急いで 出したと 知らせた。

2a. お客は オーナーに 花びんを ホステスが 静かに 見せたと 言った。
2b. お客は ホステスが オーナーに 花びんを 静かに 見せたと 言った。

3a. 先生は 大学生に 公式を 研究者が 苦労して 説明したと 話した。
3b. 先生は 研究者が 大学生に 公式を 苦労して 説明したと 話した。

4a. 不良は ウエートレスに 後輩を オーナーが 上手に 紹介したと 話した。
4b. 不良は オーナーが ウエートレスに 後輩を 上手に 紹介したと 話した。

5a. 少年は 係員に 荷物を 駅員が 無造作に 渡したと 文句をいった。
5b. 少年は 駅員が 係員に 荷物を 無造作に 渡したと 文句をいった。

6a. 運転手は おばさんに 定食を 若者達が 本当に 注文したと 知らせた。
6b. 運転手は 若者達が おばさんに 定食を 本当に 注文したと 知らせた。

7a. 弟子は 記者に カメラを 写真家が 実際は 譲ったと 認めた。
7b. 弟子は 写真家が 記者に カメラを 実際は 譲ったと 認めた。

8a. 主人は 弟子に 車を 有名人が 威張って まかせたと 言った。
8b. 主人は 有名人が 弟子に 車を 威張って まかせたと 言った。

9a. お兄さんは おばあさんに ビデオを 仲間が こっそり 貸したと 話した。
9b. お兄さんは 仲間が おばあさんに ビデオを こっそり 貸したと 話した。

10a. おばあさんは 米屋に 借金を 酒屋が 本当に 払ったと しゃべった。
10b. おばあさんは 酒屋が 米屋に 借金を 本当に 払ったと しゃべった。

11a. 歌手は オーナーに 歌を お客が 気持ち良く 褒げたと ささやいた。
11b. 歌手は お客が オーナーに 歌を 気持ち良く 褒げたと ささやいた。

12a. 女優は 監督に 手袋を 観客が 確かに 投げたと 言っていた。
12b. 女優は 観客が 監督に 手袋を 確かに 投げたと 言っていた。

13a. 婦人は 長男に かばんを 友達が ぼんやり 預けたと 説明した。
13b. 婦人は 友達が 長男に かばんを ぼんやり 預けたと 説明した。

14a. 社員は 課長に 新製品を インターンが 上手に 披露したと 伝えた。
14b. 社員は インターンが 課長に 新製品を 上手に 披露したと 伝えた。

15a. 老人は 一人娘に 土地を 親戚が 密かに 残したと 白状した。
15b. 老人は 親戚が 一人娘に 土地を 密かに 残したと 白状した。

16a. 店員は 女の子に 洋服を 高校生が ふざけて 見せてたと しゃべった。
16b. 店員は 高校生が 女の子に 洋服を ふざけて 見せてたと しゃべった。

17a. 奥さんは お母さんたちに お餅を 子供たちが 全部 焼いたと 言った。
17b. 奥さんは 子供たちが お母さんたちに お餅を 全部 焼いたと 言った。

18a. 秘書は 校長に ピアノを 調律士が 素早く 届けたと 知らせた。
18b. 秘書は 調律士が 校長に ピアノを 素早く 届けたと 知らせた。

19a. 音楽家は 踊子に 花束を 知人が 恥ずかしそうに あげていたと 言ってしまった。
19b. 音楽家は 知人が 踊子に 花束を 恥ずかしそうに あげていたと 言ってしまった。

20a. 少女は お父さんに おみやげを お姉さんが 確実に 頼んだと 嘘をついた。
20b. 少女は お姉さんが お父さんに おみやげを 確実に 頼んだと 嘘をついた。

21a. 男性は 恋人に 指輪を 売り子が 確かに おくったと 安心させた。
21b. 男性は 売り子が 恋人に 指輪を 確かに おくったと 安心させた。

22a. 男の子は 両親に キャンディを 仲良しが 何回も ねだったと 叫んだ。
22b. 男の子は 仲良しが 両親に キャンディを 何回も ねだったと 叫んだ。

23a. 先輩は 教授に 壷を 後輩が 先週 作ったと 認めた。
23b. 先輩は 後輩が 教授に 壷を 先週 作ったと 認めた。

24a. 女優は 母親に 車を 男性が 自慢気に 見せたと 言った。
24b. 女優は 男性が 母親に 車を 自慢気に 見せたと 言った。

25a. 本屋さんは 小学生に 本を お母さんが 本当に 買ったと 言ってあげた。
25b. 本屋さんは お母さんが 小学生に 本を 本当に 買ったと 言ってあげた。

Appendix 1-D.

The following is the list of stimuli used in Experiment III. These sentences were the same as the ones used in Experiment II with new adjectives and adverbs added, and the subject in the main clause was marked with the nominative particle.

1a. オフィスで地味な職員が係長に渋いお茶を女の人が出したと正直に知らせた。
1b. オフィスで地味な職員が係長に女の人が渋いお茶を出したと正直に知らせた。

2a. 東京でいやらしい訪問客が政治家に珍しい花びんを女中が見せたとしつこく言った。
2b. 東京でいやらしい訪問客が政治家に女中が珍しい花びんを見せたとしつこく言った。

3a. 教室で優しい先生が大学生に複雑な公式を研究者が説明したと静かに言った。
3b. 教室で優しい先生が大学生に研究者が複雑な公式を説明したと静かに言った。

4a. 喫茶店で生意気な不良がウエートレスにのんきな後輩をオーナーが紹介したとうるさく話した。
4b. 喫茶店で生意気な不良がウエートレスにオーナーがのんきな後輩を紹介したとうるさく話した。

5a. 京都駅できざな少年が係員に重い荷物を駅員が渡したとなまいきに文句をいった。
5b. 京都駅できざな少年が係員に駅員が重い荷物を渡したとなまいきに文句をいった。

6a. 食堂でたくましい運転手がおばさんに安い定食を若者達が注文したと元気に知らせた。
6b. 食堂でたくましい運転手がおばさんに若者達が安い定食を注文したと元気に知らせた。

7a. 田舎でけちな作家が息子にいいカメラを写真家が譲ったと正直に認めさせた。
7b. 田舎でけちな作家が息子に写真家がいいカメラを譲ったと正直に認めさせた。

8a. 京都で頑固な主人が弟子に新しい機械を有名人がまかせたとこそこそ言った。
8b. 京都で頑固な主人が弟子に有名人が新しい機械をまかせたとこそこそ言った。

9a. 住宅で面白いお兄さんがおばあさんに変なビデオを仲間が貸したとべらべら話した。
9b. 住宅で面白いお兄さんがおばあさんに仲間が変なビデオを貸したとべらべら話した。

10a. 下町で白髪のおばあさんが米屋に古い借金を酒屋が払ったとのろのろとしゃべった。
10b. 下町で白髪のおばあさんが米屋に酒屋が古い借金を払ったとのろのろとしゃべった。

11a. カラオケでうまい歌手がお父さんに短い歌をお客が捧げたと素早くささやいた。
11b. カラオケでうまい歌手がお父さんにお客が短い歌を捧げたと素早くささやいた。

12a. 大阪で下手な女優が監督に黒い手袋を観客が投げたとぼんやりと言っていた。
12b. 大阪で下手な女優が監督に観客が黒い手袋を投げたとぼんやりと言っていた。

13a. 駅で上品な婦人が長男に大切なかばんを友達が預けたと心配そうに説明した。
13b. 駅で上品な婦人が長男に友達が大切なかばんを預けたと心配そうに説明した。

14a. 会議で若い社員が課長にざん新な新製品をインターンが披露したと悔しそうに伝えた。
14b. 会議で若い社員が課長にインターンがざん新な新製品を披露したと悔しそうに伝えた。

15a. 農家でへんくつな老人が一人娘に広い土地を親戚が残したとやっと白状した。
15b. 農家でへんくつな老人が一人娘に親戚が広い土地を残したとやっと白状した。

16a. デパートでうまい店員が女の子に派手な洋服を高校生が見せてたとべらべらしゃべった。
16b. デパートでうまい店員が女の子に高校生が派手な洋服を見せてたとべらべらしゃべった。

17a. バザーで活発な奥さんがみんなにおいしいお餅を子供が焼いたと嬉しそうに言った。
17b. バザーで活発な奥さんがみんなに子供がおいしいお餅を焼いたと嬉しそうに言った。

18a. 広島で陽気な青年が校長に高いピアノを調律士が届けたと気さくに話しかけた。
18b. 広島で陽気な青年が校長に調律士が高いピアノを届けたと気さくに話しかけた。

19a. バーで貧しい音楽家が踊子に美しい花束を知人があげてたと皮肉に言ってしまった。
19b. バーで貧しい音楽家が踊子に知人が美しい花束をあげてたと皮肉に言ってしまった。

20a. 長崎で明るい少女がお姉さんに珍しいおみやげを級友が頼んだとあっさり嘘をついた。
20b. 長崎で明るい少女がお姉さんに級友が珍しいおみやげを頼んだとあっさり嘘をついた。

21a. レストランで頼もしい男性が恋人に豪華な指輪を売り子がおくったとそっと安心させた。
21b. レストランで頼もしい男性が恋人に売り子が豪華な指輪をおくったとそっと安心させた。

22a. 公園で小さい男の子が両親に大きなキャンディを仲良しがねだったと泣き声で叫んだ。
22b. 公園で小さい男の子が両親に仲良しが大きなキャンディをねだったと泣き声で叫んだ。

23a. 研究室でやり手の先輩が教授に赤い壷を後輩が作ったとしぶしぶ認めさせた。
23b. 研究室でやり手の先輩が教授に後輩が赤い壷を作ったとしぶしぶ認めさせた。

24a. 横浜で美しい女優が母親にかっこいい車を男性が買ったと苦々しく言った。
24b. 横浜で美しい女優が母親に男性がかっこいい車を買ったと苦々しく言った。

Chapter 2

Relative clause attachment in Brazilian Portuguese

Following the report by Cuetos & Mitchell (1988) that English and Spanish present different biases in the processing of a construction involving relative clauses (RCs), a large body of experimental work has investigated this construction in a number of languages. Surprisingly, however, no language tested so far has presented the same processing pattern as English. Hence, parameters proposed to explain this cross-linguistic difference have often relied on idiosyncratic features of English syntax that may correlate with its parsing preference. However, in the absence of other languages with a similar parsing bias or with the same relevant syntactic features, it has not been possible to test the generality of many of these proposals. The present paper reports experimental results in Brazilian Portuguese suggesting that this language has the same bias as English in the processing of the relevant construction. Because Brazilian Portuguese, as a Romance language, is more similar to Spanish than English in many respects, the present result allows for a number of possible sources of this cross-linguistic variation in parsing to be ruled out.

2.1 Relative clause attachment

The research on RC attachment has led to a closer scrutiny of assumptions that had often been taken to be universal across languages. In particular, several proposals in the litera-

ture favour the attachment of a modifying phrase to local heads over more distant ones in order to explain native speakers' preferences in examples like the following (Frazier, 1987; Gibson, 1991, 1998; Kimball, 1973; Phillips, 1995) .

Example (1)
I ate the ice-cream that I bought *yesterday.*

In Example (1), although the adverb **yesterday** may modify either of the underlined verbs, native English speakers prefer to associate it to the closest verb **bought**. A similar preference is not only observable in languages such as Portuguese (Example (2a)) in which the equivalent construction closely resembles the word order in English, but also in Japanese, in which the word order is markedly different (Example (2b)).

Example (2)
a. Eu tomei o sorvete que eu comprei *ontem.*
b. *Kinou* katta aisu-kurimu-o tabeta.

Furthermore, the preference to attach a modifier to the closest site available (or *locality* for short, following Gibson, 1998) correctly predicts that, in English, the RC in Example (3a) is preferentially attached to the closest noun **actress** over the non-local noun **servant**. However, in Spanish, the local attachment preference does not hold in the equivalent construction in Example (3b) (Cuetos & Mitchell, 1988).

Example (3)
a. Someone shot the servant of the actress [$_{RC}$ *who was on the balcony*].
b. Alguien disparó contra el criado de la actriz [$_{RC}$ *que estaba en el balcón*].

Native speakers of Spanish prefer to attach the RC in Example (3b) to the high noun **criado** (i.e., the highest noun available for attachment in the tree structure). Several other languages have been found to have a high attachment preference similar to Spanish (Dutch (Brysbaert & Mitchell, 1996); French (Zagar, Pynte & Rativeau, 1997); German (Hemforth, Konieczny & Scheepers, in press); results in Italian indicate an off-line preference for the high site as well (de Vincenzi & Job, 1995)). Japanese, on the other hand, presents a low attachment preference, but because the RC precedes the head nouns in this language, the comparison with head initial constructions requires taking into account factors such as immediate interpretation (see Chapter 3 for details). Restricting the discussion here to

languages in which the RC is head initial, English is the only known language to present a consistent low attachment preference both in on-line processing (Carreiras & Clifton, 1998; Henstra, 1998) as well as in off-line judgment tasks (Cuetos & Mitchell, 1988).

Moreover, no other construction tested so far, apart from Example (3), has presented a high attachment bias for RCs. For example, variations of this construction which replace the intervening preposition **de** with **con** (Gilboy, Sopena, Clifton & Frazier, 1995) or which increase the number of candidate nouns to three (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996; Gibson, Pearlmutter & Torrens, in press) have been shown to revert the RC attachment preference to the local noun. Thus, the exceptional status of Example (3b) has led most researchers to maintain the universality of the locality factor (but see the *tuning hypothesis* in Cuetos, Mitchell & Corley, 1996) by positing a second factor that competes with the local preference as it favours the highest available site.

The second factor, which favours the high site, is often assumed to be related to semantics or discourse because the high noun is the argument of a predicate. From this basic intuition, a number of proposals have been made trying to determine the exact circumstances in which this semantic factor would be relevant. According to *relativized relevance* (Frazier, 1990b), a modifier is preferentially construed as relevant to the main assertion of the current sentence. However, in sentences where an adverb may attach to either of two verbs (e.g., Examples 1 and 2; also, Kimball, 1973), relativized relevance incorrectly predicts a preference for the main verb. *Predicate proximity* (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) makes the correct prediction in this case by proposing that a modifier is preferentially attached to sites structurally closest to a predicate. A third proposal is *anaphor resolution* (Hemforth et al., in press) which further restricts the influence of the semantic factor to the attachment of relative clauses only as it suggests that semantic/discourse salience is only relevant when a relative pronoun (or a complementizer) in a RC triggers an anaphor binding process.

The proposals above allow for the universality of the locality factor to be maintained. However, if the factor favouring the high site is also the same across all languages, then some type of parametrization is necessary to account for the fact that some languages present a low RC attachment preference while others a high attachment preference. The present chapter

tests some of the factors proposed in the literature.

2.2 Parameterizing factors

Because English is the only language so far to present a consistent low attachment preference, proposed parametrizations have correlated the low attachment bias to specific features of this language. The following describes three such proposals.

One proposal associates the low attachment preference with the availability of an alternative construction to express the high attachment of RCs. In general terms, it is claimed that an ambiguous construction is less likely to be given one of its possible interpretations if this interpretation can be expressed through an alternative unambiguous construction. This would occur either because readers take Gricean constraints into account when resolving ambiguity and hence assume that speakers use unambiguous constructions whenever possible (Frazier & Clifton, 1996); or alternatively because readers choose an interpretation for a sentence based on the relative frequency that this interpretation is encountered with each of the available constructions that can express it (Thornton, Gil & MacDonald, in press). Consider the following example.

Example (4)
a. the servant of the actress [$_{RC}$ *who was on the balcony*]
b. the actress's servant [$_{RC}$ *who was on the balcony*]

In English, the high attachment of the RC in Example (4a) can also be expressed with the genitive construction as in Example (4b), whereas the low RC attachment can only be expressed through Example (4a). Hence, the RC in Example (4a) would tend to be construed as modifying the low site. This proposal makes interesting predictions about other languages in which an alternative construction exists. In particular, Dutch and German have a limited form of genitive similar to Example (4b). Although those two languages may have an overall high attachment preference in constructions such as Example (4a), the alternative construction proposal would predict them to present a low attachment preference in the specific cases where they allow the genitive alternative.

A second proposal relates the low attachment preference in English to the optionality of

complementizers in object-gap RCs (Hemforth et al., in press).

Example (5)
a. the daughter [$_{RC}$ Peter visited]
b. the daughter [$_{RC}$ *that* Peter visited]

Because of this optionality of the complementizer, the process to find an antecedent for the complementizer would not be relied upon to determine the attachment of RCs (with or without a complementizer) in English, contrary to what happens in languages where the complementizer is always obligatory. Consequently, the locality preference prevails in English. Note that reduced RCs (e.g., the proposal [$_{RC}$ advanced by the committee]) do not have a complementizer either, but this construction is also available in languages with a high attachment preference (e.g., Spanish) and therefore it cannot be responsible for the cross-linguistic variation observed in RC attachment. Hence, it will be assumed that the optionality of complementizers in RCs with object gaps is the crucial factor in this proposal.

A third parameter was proposed based on predicate proximity (Gibson et al., 1996). It suggests that in languages which allow arguments to occur after the verb in a non-adjacent position, the verb has to be activated more strongly so that enough activation is available when the non-adjacent argument is processed. Greater activation of the verb would lead to a stronger predicate proximity requirement, and hence, a stronger high attachment preference. French is one exception to this parametrization in that it has rigid SVO word order and it nevertheless presents a high RC attachment preference (Zagar, Pynte & Rativeau, 1997; but see Pynte, 1998, for a low attachment result). However, note that in French some adverbs may intervene between a verb and its direct object (Example (6a)), whereas the equivalent construction Example (6b) is ungrammatical in English.

Example (6) (Pollock, 1989)
a. Jean embrasse souvent Marie.
b. * John kisses often Mary.

If the intervention of the adverb between the verb and its direct object is enough to require extra activation of the verb, then predicate proximity should also predict French to have a high attachment preference.

2.3 Brazilian Portuguese

In order to test the predictions of the parametrizations above, an on-line experiment was conducted in Brazilian Portuguese (BP). BP is a Romance language in which the subject of a sentence does not have to be phonologically realized (pro-drop) and has to agree with the verb in person and number. Of particular interest here are the following characteristics of this language.

(I) BP does not have an alternative construction to express the high attachment of RCs, in particular, it does not have a genitive construction equivalent to Example (4b).

(II) With the exception of reduced RCs, complementizers are obligatory in RCs and in particular in RCs with an object gap.

(III) BP has rigid SVO word order and adverbs cannot intervene between a verb and its direct object.

From (I) above, the alternative construction proposal predicts that BP should have a high attachment preference. From (II), anaphor resolution also predicts a high attachment bias, whereas predicate proximity predicts a low attachment preference based on (III).

On top of variation across different languages, it has also been reported that, within the same language, constructions with virtually the same meaning present different attachment preferences. Hemforth et al. (in press) compared the attachment of non-reduced RCs and PPs in German, and found that the low site was preferred for PP attachment, while RCs were preferentially attached to the high site. This result supports Hemforth and colleagues' proposal that an overt complementizer or relative pronoun at the beginning of a RC triggers an anaphor binding process which favours attachment to the high site. Because PPs do not require anaphor binding, their attachment is presumably determined by locality alone. This proposal raises questions about reduced RCs which lack a complementizer but may still require an anaphor binding process for its null operator (see the discussion section for details). If an overt complementizer is needed in order to trigger the anaphor binding process, then reduced RCs should present a stronger low attachment preference than non-reduced RCs (full RCs for short). In order to test this hypothesis, reduced RCs were also included in the experiment to be reported next.

2.4 Method

2.4.1 Participants

Forty-two native speakers of BP, residents in the Boston area, participated in the study. One participant was eliminated for answering the comprehension questions at chance. A second participant was eliminated for having very slow reading times (see analysis section below).

All remaining 40 participants learned English as adults and had been in the United States between one week and 15 years at the time when they participated in the study (M = 25.8 months; SD = 34.9 months).

Because most participants also spoke English, there is the possibility that they transferred the parsing biases from this second language to BP, their first language. However, a study with native speakers of Spanish residents in the Boston area found a high attachment preference in the equivalent Spanish construction without any apparent influence from English (Gibson, Pearlmutter & Torrens, in press). Thus it will be assumed here that if BP has a high attachment preference then it should also be detectable in the present experiment despite the participants' proficiency in English.

2.4.2 Materials

The 2x2 design included type of RC (full and reduced) and attachment site (high and low). All 32 items were presented in BP as seen in Appendix 2-A.

The difference between the full (Examples (7a) and (7b)) and the reduced RCs (Examples (7c) and (7d)) is that the latter construction does not contain the complementizer que or the auxiliary verb foram.

Example (7)

a. Full RC, high
A kombi trouxe os supervisores do engenheiro [$_{RC}$ que *foram pagos* pela empreiteira].

b. Full RC, low
A kombi trouxe o supervisor dos engenheiros [$_{RC}$ que *foram pagos* pela empreiteira].

c. Reduced RC, high
A kombi trouxe os supervisores do engenheiro [$_{RC}$ *pagos* pela empreiteira].

d. Reduced RC, low
A kombi trouxe o supervisor dos engenheiros [$_{RC}$ *pagos* pela empreiteira].

The van brought the$_{(plural)}$ supervisor(s) of the$_{(plural)}$ engineer(s) [$_{RC}$ (that were) paid$_{(plural)}$ by the company].

Note that both verbs in the RC (**were** as well as the participial verb **paid**) have to agree in number and gender with the head noun that the RC modifies. The present experiment only manipulated number in order to disambiguate the attachment site for the RC. As can be seen in Example (7), number is kept constant on the verb inside the RC, and the number on the underlined head nouns is manipulated. Hence, the RC has to be attached to the high noun in Examples (7a) and (7c), and to the low noun in Examples (7b) and (7d). The disambiguating region (in italics in Example (7)) for the full RCs include the auxiliary verb **be** and the participial verb, whereas in the reduced RCs only the participial verb indicates the correct interpretation.

2.4.3 Procedure

The experiment was conducted on a Power Macintosh 7500/100. The self-paced reading moving-window program presented sentences (Just, Carpenter & Woolley, 1982) one word at a time in a non-cumulative fashion. Stimulus words initially appeared as dashes, and participants pressed the spacebar on the keyboard to reveal each subsequent word of the sentence and cause all other regions to revert to dashes. A yes/no question was presented after each sentence and feedback was provided each time a mistake was made. The experimental trials were preceded by instructions and eight practice trials. The experiment took participants approximately 20 minutes. Participants read eight sentences for each of the four conditions in a Latin Square design. These 32 sentences were presented intermixed with 62

filler items in pseudo-random order. See Appendix 2-A for the list of test stimuli used.

Most of the self-paced reading experiments investigating RC attachment have used a coarse-grained segmentation in which the first region includes all words up to the second head noun (e.g., Someone shot the servant of the actress) and the second is the crucial region with the RC (who was on the balcony). However, this type of segmentation may indicate to participants the main region of interest in the stimuli. An alternative more fine-grained region presentation has also been used in which the head nouns in the complex NP are shown in two separate regions (e.g., one region contains the servant and the ensuing region of the actress; de Vincenzi & Job, 1995). However, this latter presentation has been claimed to induce a low attachment preference (Carreiras & Clifton, 1993) and experimental evidence suggests that no preference in attachment site is detectable when this type of segmentation is used in Spanish (Gilboy & Sopena (1996)). The third alternative, adopted in the present experiment, is to use a word-by-word presentation, which does not emphasize any one region in the stimuli and does not seem to bias participants towards low attachment given that a high RC-attachment preference has been detected in Spanish using this type of presentation (Gibson, Pearlmutter & Torrens, in press).

2.4.4 Data analysis

Analyses were performed on comprehension question response accuracy and on reading times (both raw and residual). A linear regression between word lengths and reading times was performed on each participant's data set (Ferreira & Clifton, 1986; Trueswell, Tanenhaus & Garnsey, 1994). The portion of the reading time predicted by the length of the word was subtracted from the original raw reading time, yielding a residual reading time. Furthermore, the data were trimmed so that data points beyond 3.5 standard deviations from the relevant condition $\times$ region cell mean were discarded, corresponding to less than 2% of the total data points. The analyses only included the items for which the participants answered the comprehension question correctly.

One participant was eliminated because of slow reading times. The slope in the regression equation, in particular, was 312 ms/char in contrast to the other 40 participants whose slopes

ranged from 6 to 163 ms/char (M = 39.6; SD = 31.5).

For analysis purposes only, the stimulus words are collapsed into regions as follows (see Table 2.1). The first region contains the main-clause subject (a head noun and in some cases a specifier). The second region contains the main verb (including auxiliary verbs). The third region contains the article for the object NP. The fourth region is the first head noun (the high attachment site). The fifth region contains one word, namely, the preposition of with a definite article. The sixth region contains the second head noun, which is the low site candidate for attachment. For the full RCs, the complementizer and the verb to be (foram in Example (7)) were coded separately as individual regions. The seventh word is the participial verb in the RC. Each of the remaining words in the RC was coded as a single region.

Region	1	2	3	4	5	6	7	8	9
Words	subject	verb	article	noun_1	of+article	noun_2	(comp. be) verb	(rest of the RC)	
Example	the van	brought	the	supervisors	of-the	engineer	(that were) paid	by-the	company

Table 2.1: Regions used for analysis

Eleven items had exactly nine regions as shown in Table 2.1. The other 21 items had longer RCs, but in all cases at least the first nine regions were presented on a single line on the computer screen. A linebreak, when present, occurred at later regions. Eleven items had ten regions, eight items had eleven regions, and two items had twelve regions.

2.4.5 Norming study

In order to ensure that attachment to the two sites is equally plausible, a survey was conducted in which participants were asked to judge the plausibility of each attachment. Each of the thirty-two items used in the on-line experiment was separated into two sentences. The first sentence corresponded to the main clause, and the second sentence contained the RC with the gap filled with one of the two head nouns. In one version, the RC gap was filled with the high noun and in the second version with the low noun. For instance, Example (7) above would correspond to the following two versions.

Example (8)

a. *High attachment.*
A kombi trouxe o supervisor dos engenheiros.
O supervisor tinha sido pago pela empreiteira.
"The van brought the supervisor of the engineers.
The supervisor had been paid by the company."

b. *Low attachment.*
A kombi trouxe os supervisores do engenheiro.
O engenheiro tinha sido pago pela empreiteira.
"The van brought the supervisors of the engineer.
The engineer had been paid by the company."

The version in Example (8a) corresponds to the high attachment of the RC, whereas Example (8b) corresponds to the low attachment condition. Participants were asked to judge the plausibility of such pairs of sentences in a scale from 1 ("natural") to 7 ("strange"). Each participant only saw one version per item and they did not participate in the on-line experiment. Twenty-five native speakers of BP, residents in São Paulo, took part in the survey. The means for the high (3.08) and the low attachment condition (2.90) were not significantly different (Fs <1). Linear regression analyses detected no correlation between the plausibility judgements and the residual reading times (at regions 7 and 8) using the difference between the high and the low attachment conditions for each item ($r^2 < 0.1$, ps > 0.17).

2.5 Results

In the comprehension question response accuracy, there was a significant interaction between RC type and attachment site ($F_1(1,39) = 8.86$, $p < 0.01$; $F_2(1,31) = 8.81$, $p < 0.01$). Performance for reduced RCs was significantly better in the low site attachment condition (79%) than in the high attachment condition (66%; $F_1(1,39) = 17.69$, $p < 0.01$; $F_2(1,31) = 5.17$, $p < 0.05$). For full RCs, however, performance in the low attachment condition (72%) was only numerically better than the high attachment condition (69%; Fs < 1).

The following are the results of the analyses using residual reading times, which are presented in Figures 2.1 and 2.2. The same pattern of results was obtained in the analyses

with raw reading times.

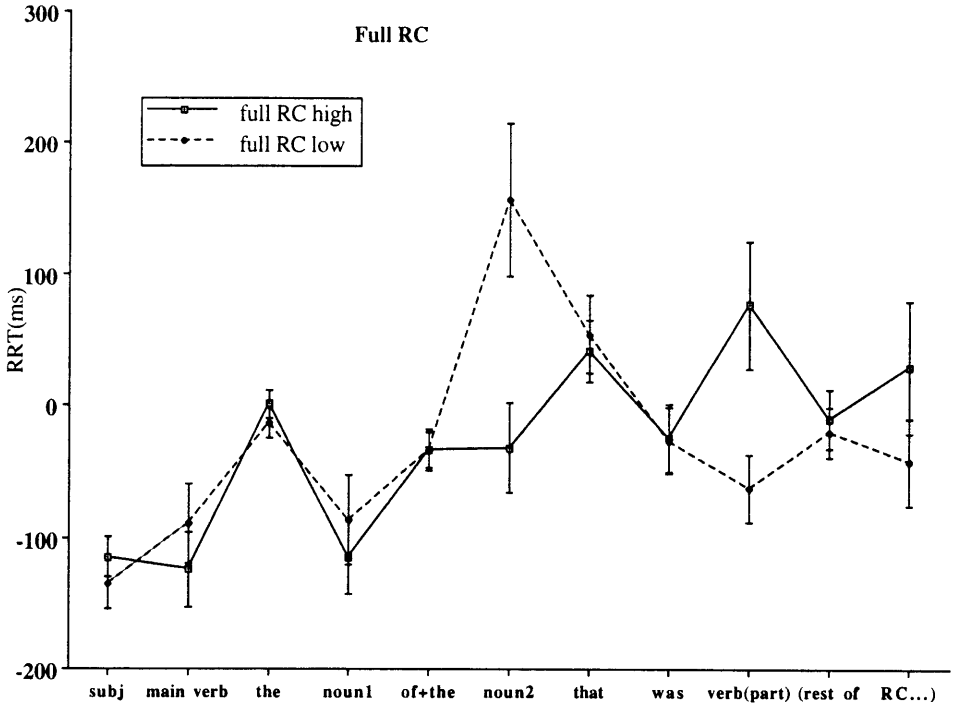

Figure 2.1: Residual reading times for full relative clauses.

Analyses for each of the fist five regions yielded no differences between the four conditions (Fs < 1). Neither were there differences between the low and high attachment conditions at the complementizer or at the auxiliary verb **be** with full RCs.

In region 6 (the second head noun), the results were as follows. The low and high attachment conditions did not differ for reduced RCs ($F_1(1,39) = 1.84$, $p = 0.18$; $F_2 < 1$). With full RCs, the low condition was significantly slower than the high attachment condition ($F_1(1,39) = 6.99$, $p < 0.05$; $F_2(1,30) = 11.2$, $p < 0.01$). Moreover, the low attachment condition with full RCs was marginally slower then the low attachment condition with reduced RCs ($F_1(1,39) = 3.81$, $p = 0.058$; $F_2(1,31) = 4.53$, $p < 0.05$), although both conditions presented the same words up to this point. This slow reading time in the low attachment condition with full RCs seems to persist in regions 7 and 8 in that the items that are slowest in region 6 are also the ones that presented the slowest reading times in regions 7 and 8.

The analysis at the reduced RCs had the following results. In region 7 (the participial verb

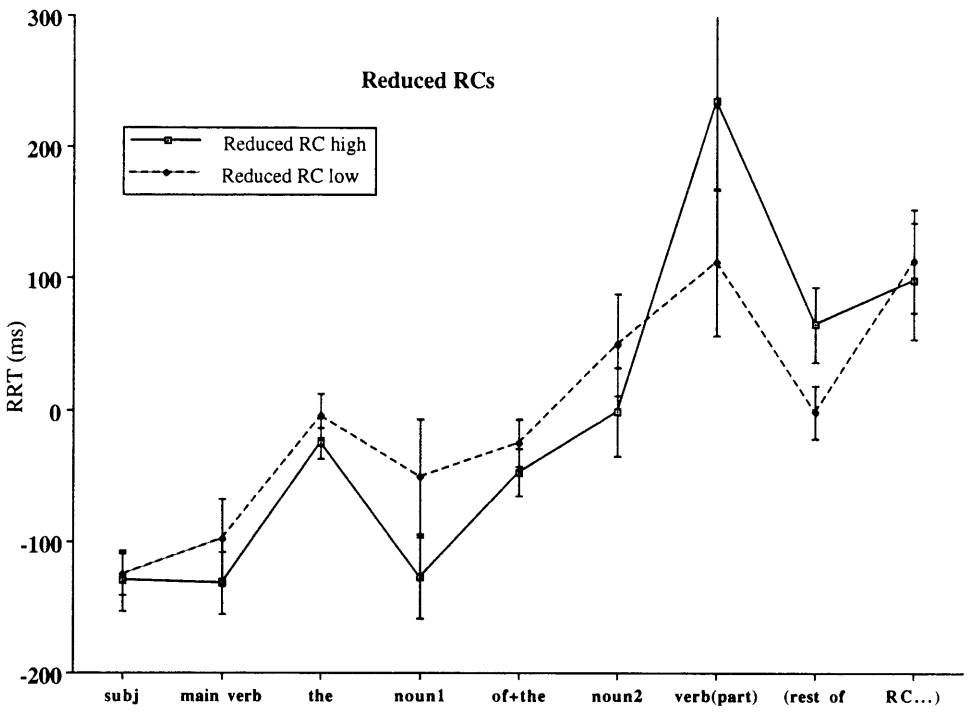

Figure 2.2: Residual reading times for reduced relative clauses.

in the RC), the low attachment condition was significantly faster than the high attachment condition in the analysis by subjects but not by items ($F_1(1,39) = 4.96$, $p < 0.05$; $F_2(1,31) = 2.23$, $p = 0.14$). In region 8, the low was significantly faster than the high attachment condition both by subjects and by items ($F_1(1,39) = 4.25$, $p < 0.05$; $F_2(1,30) = 8.30$, $p < 0.01$). In region 9, the low and high attachment conditions did not differ ($Fs < 1$).

In the full RCs the results were as follows. In region 7, the low was faster than the high attachment condition ($F_1(1,39) = 6.46$, $p < 0.05$; $F_2(1,30) = 5.51$, $p < 0.05$). There was no difference in region 8 ($Fs < 1$). In region 9, the low was faster than the high attachment condition, but the difference was not significant ($F_1(1,39) = 2.79$, $p = 0.103$; $F_2 < 1$).

In regions 7, 8, and 9, the reduced RCs were significantly slower than the full RCs ($ps < 0.05$). In the items with more than nine regions, there were no significant differences in regions 10, 11 and 12, only a tendency for reduced RCs to be slower than full RCs.

Previous studies have reported a stronger advantage for low attachment when the verb has singular marking (Cuetos, Mitchell & Corley, 1996; Gibson, Pearlmutter & Torrens, in

press, N. Pearlmutter through personal communication). Hence, a more detailed analysis was conducted for region 7, which contains the participial verb inside the RC. In the present experiment, verb number was kept constant within each item, but it varied across items. Fifteen items had plural marking on the verb and the other 17 items had singular verbs. Because of a mistake, the stimulus lists did not counterbalance for verb number. Collapsing regions 7 and 8, a significant interaction was detected in the analysis by items when considering number and attachment site ($F_2(1,30) = 6.791$, $p < 0.05$). This is because the difference between the low and high attachment conditions is only significant with singular verbs ($F_2(1,16) = 12.12$, $p < 0.01$) and not with plural verbs ($F_2 < 1$). However, in the present case, this effect is confounded by the fact that the items with plural verb that are slowest in regions 7 and 8 were also responsible for the unexplained slow-down in region 6 in the low attachment condition. Moreover, there was no interaction between number marking and attachment site in comprehension performance ($F_2 < 1$).

2.6 Discussion

Both comprehension performance and reading times suggest that the low attachment of RCs is preferred in BP. In the following, the results are discussed separately for reduced and non-reduced RCs.

2.6.1 Non-reduced RCs and parsing parametrizations

The slow reading time in region 6 (the second head noun) in the low attachment condition with full RCs continues in the critical regions (7 and 8), apparently decreasing the advantage of the low over the high attachment condition, nevertheless the former condition is still significantly faster in the critical regions.

The low attachment preference detected with full RCs in the critical regions does not agree with the predictions made by the proposals based on the availability of an alternative construction (Frazier & Clifton, 1996; Thornton, Gil & MacDonald, in press) or based on the optionality of complementizers in object-gap RCs (Hemforth et al., in press). On

the other hand, the result supports the parametrization proposed by predicate proximity (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) and suggests that rigid word order may indeed correlate with the low attachment preference of full RCs. Considering the similarities between Spanish and BP, their most marked difference is in word order flexibility. Although BP allows some types of topicalizations (see Kato & Raposo, 1996, for topicalizations allowed in Brazilian and in European Portuguese), overall it presents rigid SVO word order. Predicate proximity proposes that flexible word order requires stronger activation of verbs and consequently more salient argument heads. Another reason for word order flexibility to correlate with high attachment is that it may require native speakers to be more attentive to where exactly clause boundaries lie in comparison to languages with rigid word order, in which clause boundaries are more predictable. Such attention to clause boundaries may make them more salient in languages with flexible word order and thus weaken the locality effect between a RC and the immediately preceding head noun.

Moreover, it is conceivable that flexible word order may also require more salient pauses between clauses in speech, in which case, the relation between the resulting prosodic contour and RC attachment preference may not be of causality (Fodor, 1998), but rather both may be by-products of word-order flexibility.

2.6.2 Reduced RCs and anaphor resolution

According to reading times and comprehension question performance, reduced RCs are preferentially attached to the low site. Moreover, the low attachment preference is stronger with reduced RCs than with full RCs, as the interaction in comprehension performance indicates. The following discusses a few proposals to explain the weaker low attachment bias when a complementizer is present.

This pattern of results is in accordance with the anaphor resolution proposal (Hemforth et al., in press). Because an anaphor resolution process (ARP for short) is not triggered by reduced RCs, attachment is presumably determined by locality alone. However, there are a number of issues that should be considered in this proposal. From a generative grammar point of view, reduced RCs have a null operator which requires an antecedent in the discourse

(see Haegeman, 1994, and references therein). Hence, an ARP should also be taking place during the attachment of reduced RCs. But, in the absence of the complementizer, it is conceivable that the ARP is triggered too late to influence the attachment decision (see Hemforth, Konieczny & Scheepers, 1997, for details of a race model in which the locality factor and the ARP compete to provide an attachment site as early as possible). Consider the following example.

Example (9)

A kombi trouxe o supervisor do engenheiro $[_{RC}$ pago pela empreiteira].
the van brought the supervisor of engineer paid by-the company

"The van brought the supervisor of the engineer paid by the company."

In the reduced RC in Example (9a), the ARP is triggered at **paid**, the first word where it is clear that a null operator is required. Because **paid** itself does not require an antecedent, there may be a delay before the ARP starts in order to posit the null operator, hence giving an advantage to the locality factor. However, this delay cannot explain the difference between reduced and non-reduced RCs because complementizers also require such delay. So far, in this discussion, complementizers and relative pronouns have been undifferentiated, however, strictly speaking, only relative pronouns require an antecedent whereas a complementizer in a RC has a null operator as its specifier, and it is this operator that requires an antecedent. For processing purposes, the complementizer is the first overt word at which point it is clear that such null operator is present, hence this is where the ARP may be triggered. In this case, the processing of complementizers should also involve a delay in order to posit the null operator and therefore a temporal advantage should be expected for the locality factor, but in this case the difference between reduced and non-reduced RCs would not be explained. It may be suggested then that during the processing of a full RC the complementizer itself requires an antecedent as it is compounded with the null operator into a single constituent (see for example Pesetsky, 1981, which explains **que-qui** alternations in French based on a proposal that null operator and complementizer may merge as a single element.)

An alternative explanation for the fact that complementizers weaken the locality preference may be that they signal the beginning of a new clause hence decreasing the perception that the incoming constituent (the RC) is part of the previous constituent (the NP headed by

the low noun). In closure terms (Frazier, 1987; Kimball, 1973), the low or high attachment of an RC corresponds to the late or early closure of the NP headed by the local noun. The proposal here then would be that closure will be influenced by the salience of the boundary that initiates the modifier. A marked boundary (as indicated by a complementizer) would make the modifier less likely to be construed as part of the low NP.

A third alternative explanation may be that the distance from a functor in a modifier to the modified head determines the strength of the locality preference, where a functor is the predicate that takes the modified head as one of its arguments. For example, in the RC in the German Example (10a) below, the functor is the verb **came**, whereas in the PP in Example (10b), it is the preposition **from**.

Example (10) (Hemforth, Konieczny & Scheepers, in press)

a. Die Tochter der Lehrerin, [$_{RC}$ die aus Deutschland kam], traf John.
the daughter the$_{Gen}$ teacher who from Germany came met John

"The daughter of the teacher who came from Germany met John."

b. Die Tochter der Lehrerin [$_{PP}$ aus Deutschland] traf John.
the daughter the$_{Gen}$ teacher from Germany met John

"The daughter of the teacher from Germany met John."

Thus the functor in Example (10b) is closer to the local noun **teacher** than in Example (10a), correctly predicting that the local attachment is stronger with PPs than RCs (Hemforth, Konieczny & Scheepers, 1997). In the reduced RC in Example (9a), the functor **paid** is closer to the low noun **engineer** than in the full RC in Example (9b), and consequently the stronger low attachment preference in the former construction follows. Another phenomenon that may be captured by this proposal is that longer modifiers tend to attach high more strongly than short modifiers (Fodor, 1998; Pynte, 1998), which follows from assuming that functors in longer modifiers tend to occur further from the modified head. The notion that distance between constituents affects attachment preferences can be formalized in terms of an integration cost (Gibson, 1998) incurred in the present case when the functor of the modifying phrase is processed.[1]

[1]In order to use such integration cost however, a more elaborate explanation may be needed in order to

Future work comparing the three proposals above should provide further insight on the RC attachment phenomenon.

2.7 Conclusion

The low attachment preference of full RCs in Brazilian Portuguese reported in this chapter agrees with the proposal that word order flexibility (as in Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996) is responsible for the cross-linguistic difference observed between English and other languages such as Spanish. Some possible reasons for this causality relation were considered.

A number of proposals were also discussed in relation to the stronger low attachment preference observed with PPs and reduced RCs when compared to full RCs. Some questions raised by the syntax of reduced RCs were considered in relation to the attachment of modifiers in general, and especially concerning the anaphor resolution process (Hemforth, Konieczny & Scheepers, in press).

account for intermediate traces.

Appendix 2-A.

Items used in the on-line experiment. All four conditions are provided for item 1. For the other items, the three last conditions can be obtained from the first condition by inverting the number on the two head nouns (conditions (b) and (c)) and by eliminating the complementizer and the auxiliar (conditions (c) and (d)).

1a. Uma aluna criticou os professores do curso que foram escolhidos pelos estudantes.
1b. Uma aluna criticou o professor dos cursos que foram escolhidos pelos estudantes.
1c. Uma aluna criticou os professores do curso escolhidos pelos estudantes.
1d. Uma aluna criticou o professor dos cursos escolhidos pelos estudantes.

2a. A rádio transmitiu a apresentação das orquestras que foi patrocinada pelo governador.

3a. A kombi trouxe os supervisores do engenheiro que foram pagos pela empreiteira.

4a. O museu exibiu a pintura das paisagens que foi descrita por Machado de Assis.

5a. O banco recusou os empréstimos do apartamento que foram examinados pelo gerente o mês passado.

6a. O arcebispo condenou a atriz das novelas que foi taxada de indecente pela igreja.

7a. O piloto tentou mirar nos motores do bombardeiro que tinham sido avariados no início da batalha.

8a. O cientista obteve a lente das câmeras que foi apresentada no congresso de optometria.

9a. Daniel checou as paredes da casa que foram arruinadas pelas enchentes.

10a. O eletricista checou o cabo dos aparelhos que foi danificado no dia da inauguração.

11a. A polícia apresentou os suspeitos do assassinato que foram investigados pelo delegado.

12a. A modista redesenhou a manga das jaquetas que foi criada pelo dono da loja.

13a. A dona-de-casa preparou as receitas da cozinheira que foram premiadas o ano passado.

14a. Eduardo trabalha com o advogado dos sindicalistas que foi envolvido no caso de maneira imprevista.

15a. Os solistas ensaiaram os concertos do compositor que foram redescobertos na Itália

recentemente.

16a. O ca cador capturou o leão dos amestradores que fora criado desde pequeno no circo.

17a. O professor se referiu às tradu cões da estória que foram elogiadas no jornal americano.

18a. O maestro ficou satisfeito com a grava cão das músicas que foi escolhida pela companhia.

19a. O prefeito fez questão de visitar o projeto dos prédios que foi premiado pelo museu alemão.

20a. O mordomo serviu o convidado dos anfitriões que foi acusado de extelionato pela imprensa.

21a. O repórter ridicularizou os participantes do concurso que foram patrocinados pela prefeitura.

22a. O camponês avistou o pastor dos carneiros que fora atacado pelos lobos.

23a. A atriz gostou dos scripts do escritor que foram elogiados pela imprensa européia.

24a. O ator tentou ignorar a manchete das revistas que foi mencionada no rádio.

25a. O carrasco executou os conselheiros do embaixador que foram exilados de seu país.

26a. O jornalista investigou o encontro dos sindicalistas que foi cassado pela junta militar.

27a. O general teve que reavaliar os resumos do livro que foram censurados pelos militares.

28a. A agência não gostou da propaganda das companhias que tinha sido sugerida pelo publicitário.

29a. O cientista examinou os predadores do herbívoro que foram dissecados durante o experimento.

30a. O arqueólogo re-catalogou o fóssil dos dinossauros que fora descrito incorretamente no panfleto.

31a. O astrônomo confirmou as trajetórias da constela cão que foram estudadas na Idade Média.

32a. O juiz elogiou a testemunha das carnificinas que foi filmada secretamente pela imprensa.

Chapter 3

Relative clause attachment in Japanese[1]

In the sentence processing literature, principles such as *right association*, *late closure*, and *locality* have often been assumed to apply universally across languages, favouring the interpretation in which a modifying phrase is attached to the closest possible site (Frazier & Fodor, 1978; Gibson, 1991, 1998; Kimball, 1973; Phillips, 1995). Recent proposals by Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok (1996) and Hemforth, Konieczny & Scheepers (in press) have refined this view by suggesting factors that modulate locality, so as to account for cross-linguistic results in the attachment of relative clauses (RCs) (see Cuetos, Mitchell & Corley, 1996, for a recent overview). The purpose of the present paper is to investigate the attachment preferences of head-final RCs in Japanese.

Reading time evidence presented by Gibson et al. (1996) showed that, in sentence fragments such as Examples (1a) and (1b) with three potential host nouns, native speakers preferred to attach the RC to the low noun (i.e., N_3, the lowest candidate noun in the tree structure) both in Spanish and in English. Furthermore, attachment to the high noun (N_1) was preferred over the middle noun (N_2). Similar results were obtained with complete sentences in Spanish (Gibson, Pearlmutter & Torrens, in press) and German (Walter & Hemforth, 1998), but a high over low attachment seems to be preferred in Dutch (Wijnen, 1998).

[1]This work was conducted in collaboration with E. Gibson, N. Pearlmutter, T. Aikawa and S. Miyagawa.

Example (1) *head-initial RCs*

	N_1		N_2		N_3	RC
a.	la(s) lámpara(s)	cerca de la(s)	pintura(s)	de la(s)	casa(s)	[que fue dañada en la inundación]
b.	the lamp(s)	near the	painting(s)	of the	house(s)	[that was damaged in the flood]

The overall preference for low attachment found by Gibson et al. (1996) is compatible with locality. However, the advantage of the high over the middle noun is not. In order to explain this U-shaped preference curve (i.e., with the middle noun as the least preferred site), Gibson et al. (1996) proposed a second factor which prefers the attachment of the modifying phrase to the high site (N_1) and therefore competes with locality. The attachment preference then results from the interaction of these two factors. More specifically, these authors proposed the *predicate proximity* principle, according to which modifiers are preferentially attached to the phrase closest in structural terms to the predicate of the sentence. In the construction in Example (1), predicate proximity is not strong enough to override locality, hence the preference for N_3. But it is strong enough to yield the preference for N_1 over N_2.

Hemforth, Konieczny & Scheepers (in press; 1997) suggested an alternative proposal in which the factor favouring the attachment of a RC to the higher site is related to the process of finding the antecedent for the relative pronoun in the RC (e.g., who in English). This process is biased towards discourse salient entities such as the head of a complex NP (e.g., N_1 in Example (1)).

The purpose of this paper is to explore some aspects of RC attachment when three potential host nouns are available. In particular, we will consider the case in which the RC precedes the head nouns and is not initiated by a complementizer or a relative pronoun, as in Example (2).

Example (2) *head-final RCs*
RC N_3 postposition N_2 postposition N_1

In Example (2), we have the head-final RC construction in languages such as Japanese, Korean and Tamil, which have postpositions rather than prepositions and therefore present the nouns in the opposite order to that of head-initial languages (cf. Example (1)). In structural terms, the noun closest to the RC (N_3) is still the lowest, and the farthest one (N_1) is the highest noun available for attachment inside the complex NP.

Assuming an incremental parser, which processes each incoming word immediately and tries to integrate it without delay to the phrase marker built so far (e.g., Marslen-Wilson & Tyler, 1980, 1981), the positioning of the head nouns after the RC in the head-final RC construction makes it particularly interesting to compare to its head-initial counterpart. In head-initial RC constructions, the attachment decision is made after the three nouns have been encountered. In head-final RCs, however, the RC is processed first and only then are the nouns detected. Hence, under an incremental model, the parser should attempt to attach the RC to each incoming noun in turn until a successful attachment is made. Because the first noun (N_3) is the only available candidate initially, it is natural to expect it to be the most preferred site for attachment. If attachment to the first noun is not successful, incrementality predicts that the middle noun is favoured over the high noun as the parser attempts to resolve the attachment as soon as possible.

However, this overlooks an important factor in the processing of head-final constructions. In such constructions, the parser's decisions may be influenced by a category that is predicted to be upcoming in the input string. Evidence that predicted categories influence the parser's behaviour is provided by Yamashita (1994) who showed that native Japanese speakers do not wait for the detection of a verb in order to start interpreting a sequence of NPs. Instead these NPs are interpreted as the arguments of a predicted verb whose features are only partially determined by the case markers on those NPs.

Thus, when discussing the processing of head-final RC constructions with multiple potential heads, it is necessary to consider whether there is partial information predicting a category, and, if so, how such information could affect the attachment of the RC. First, partial information may be available in this construction in the form of a particle (e.g., a postposition) marking a noun being processed, which indicates that a higher noun is to come. For example, when processing N_3 in Example (2) above, the parser may be already predicting another noun because of the postposition that immediately follows N_3. Assuming that such a particle does predict a higher noun, there are two alternative ways for the parser to treat such partial information with respect to attachment decisions. It is conceivable that the parser only takes into account candidate sites whose heads have already been lexically realized. We will refer to this alternative as parsing with lexically-realized candidates only, or

LexCat-parsing. Alternatively, the parser may also consider attaching the RC to a predicted site whose head is still to be processed, even if a lexically-realized candidate is already available. We will refer to this alternative as parsing with predicted categories as candidates, or *PredCat-parsing.* Consider the predictions that LexCat- and PredCat-parsing make in the head-final RC construction with three candidate sites. In LexCat-parsing, only lexically-realized sites are considered, hence the parser favours attachment to the nouns in the order they become available — low, middle, high — a monotonic decreasing preference ordering of the sites. In PredCat-parsing, however, both predicted as well as lexically-realized sites are considered as candidates for attachment. Therefore it is possible that an upcoming site may be preferred over a site already available depending on the interplay between locality and the factor(s) favouring the higher site. In particular, an alternative to the monotonic prediction is suggested by the U-shaped curve obtained by Gibson et al. (1996) in the head-initial RC construction. Such a U-shaped result, or any result where a higher site is preferred over a lower one, would be compatible with PredCat-parsing, but not with LexCat-parsing.

Kamide and colleagues provide some suggestive evidence for PredCat-parsing in two self-paced reading experiments testing the attachment of head-final RCs with two potential hosts in Japanese. In the first experiment, Kamide & Mitchell (1997) reported an initial advantage for low attachment, supporting locality. In a follow-up experiment (Kamide, Mitchell, Fodor & Inoue, 1998), the segmentation for their self-paced presentation was modified so that, contrary to the presentation in the original experiment, the first head noun and the following particle (the genitive marker no) were presented in the same region. Although the low condition was still faster than the high condition, this difference was no longer significant. This suggests that locality was weakened by the visibility of the genitive marker, which signalled that another site was upcoming. However, this is a null result, and more convincing evidence in support of PredCat-parsing would be results showing a preference to attach a head-final RC to a higher candidate over a lower one.

The PredCat/LexCat distinction interacts with proposals made in the literature to account for the attachment of modifiers. In the proposal by Hemforth, Konieczny & Scheepers (in press; 1997), two independent processes compete and the first to come up with a candidate site is the winner. In this model, which we will refer to as the *race model*, one

process involves syntactic factors which favour the closest site (locality), whereas the second process is anaphor resolution, that is, finding the antecedent for the relative pronoun of a RC. The anaphor resolution process in itself can favour either type of site, predicted or lexically-realized, as it does not necessarily require a lexical item or a fully specified entity. The race component of the model, however, implies that the winner is the entity that displays the higher activation level at the earliest possible point. Because predicted sites do not have a corresponding activated entity in the discourse, the race component of this model requires that only lexically-available sites be considered as potential sites, in accordance with LexCat-parsing. In this fashion, it is immaterial that the anaphor process prefers the high noun for discourse salience reasons, as this noun only becomes available later in the sentence. Thus, the race model predicts a monotonic preference ordering among the sites (namely, N_3, N_2, N_1) and would be contradicted by a U-shaped result. Note that here, we can dissociate two components of the race model. On the one hand, there is the race component itself, arguing for the earliest, most activated entity in the discourse. On the other hand, there is the anaphor resolution process, favouring the higher sites for discourse reasons, which could be interpreted within a model distinct of a race metaphor.

The same monotonic prediction is made by *parameterized head attachment* (Konieczny, Hemforth, Scheepers & Strube, 1997) which explicitly assumes LexCat-parsing. According to this proposal, arguments and modifiers should be preferentially associated with a lexically-realized head, disfavouring predicted categories and implying in the present construction that the nouns are preferred in the order that they become available.

Predicate proximity (Gibson et al., 1996), on the other hand, is not bound to PredCat- or LexCat-parsing. In this proposal, the factor favouring higher sites is related to their closer structural proximity to the main predicate of the clause, which in itself requires neither that the potential candidates must all be lexically-realized nor that predicted categories should be taken into consideration. Considering that the discourse salience in Hemforth and colleagues' anaphor resolution process may have its origin in a predicate proximity-like factor (Hemforth, Konieczny & Scheepers, 1997, fn. 8), it should not be surprising that both principles present a similar neutrality in relation to partial information use, which allows them to be interpreted within a LexCat- or a PredCat-parsing framework. Within a LexCat-

parsing framework, the preferences of either predicate proximity or anaphor resolution for the high site would be irrelevant because this site would only be lexically available later than lower sites, and as a result the prediction for a monotonic ordering of the potential sites should still follow. In PredCat-parsing, the predictions would depend on the weights that one assigns to the strength of the factors favouring the low site (locality) and the high site (predicate proximity or anaphor resolution) at each point during the processing of the RC heads. With the exception of the middle site being preferred overall, such assignment of weights within PredCat-parsing could account for most outcomes in the present experiment, but if the weights of the factors at play in the head-final RC construction should mirror the ones proposed for head-initial RCs (Gibson et al., 1996), then a U-shaped preference ordering of the sites would be the expected result.

More generally, there are clearly two distinct predictions being made in relation to attachment preferences in head-final RC constructions with three head nouns. First, there is the prediction for a monotonic curve with the middle (N_2) being preferred over the high (N_1). And second, there is the prediction for a U-shaped curve, in which the middle site (N_2) is the least preferred. In both cases, the most local site (N_3) is predicted to be the most preferred. We investigated these predictions in the head-final RC construction with three potential attachment sites in Japanese.

3.1 Method

3.1.1 Participants

Thirty-nine native speakers of Japanese participated for $20 each. They had all come to the U.S. as adults and were residents of the Boston area. One participant was eliminated for answering the comprehension questions at chance level, and two were eliminated because of extremely long or short baseline reading times (see the Analysis section for details).

3.1.2 Materials

Sentences like those in Example (3) were presented using Japanese characters, with the attachment of the RC disambiguated by plausibility. In Example (3a), the RC is biased towards the low site (N_3); in Example (3b), towards the middle site (N_2); and in Example (3c), towards the high site (N_1). Appendix 3-B contains a complete list of the stimuli. The potential attachment sites are underlined in Example (3); the slashes indicate the divisions between regions for the self-paced reading presentation.

Example (3) *head-final RCs*

a.

	RC	/ N_3	$postp_1$	/ N_2	$postp_2$	/ N_1-topic	/ $pred_1$	/ $pred_2$
$[_{RC}$	Eda-ga oreteiru]/	shigemi-no	yoko-no/	hito-no	ushiro-no/	jitensha-wa/	kireide/	ooki-katta
	branch-Nom broken /	bush	beside /	person	behind /	bicycle-Top /	pretty /	big-was

b.
$[_{RC}$ Paati-de atta]/ ...
party-Loc met

c.
$[_{RC}$ Gakkou-made notta]/ ...
school-to rode

'The bicycle behind the person beside the bush that *has a broken branch* was pretty and big.'
I met at the party
I rode to school

In order to control for potential lexical and plausibility differences, the three head nouns were rotated through the three attachment sites for each of the three plausibility-biased RCs, yielding a total of nine sub-conditions, as schematically represented in Table 3.1.2.

Because of the plausibility biases, each RC in Table 3.1.2 has to attach to the same noun (as the subscripts A, B, C indicate), but the position of the noun itself varies from condition to condition. For example, the RC **met at the party** should always attach to **person**, but the position of this head noun (high, middle or low) will depend on the subcondition that the participant sees.

In the segmentation of the sentences for the self-paced reading presentation, regions 2 and 3 include a head noun and a postposition together. Words are not usually separated by spaces in written Japanese, hence there is no a priori natural way to segment the regions. However, two factors led us to display each PP (i.e., a postpositional phrase comprised of a postposition with its preceding noun) as a single region. First, particles such as **no** (which

Condition		Region 1	2	3	4	5	6
Low	(a)	RC_A	N_A $postp_1$	N_B $postp_2$	N_C topic	$pred_1$	$pred_2$.
Mid	(b)	RC_B	N_A $postp_1$	N_B $postp_2$	N_C topic	$pred_1$	$pred_2$.
High	(c)	RC_C	N_A $postp_1$	N_B $postp_2$	N_C topic	$pred_1$	$pred_2$.
Mid	(d)	RC_A	N_C $postp_1$	N_A $postp_2$	N_B topic	$pred_1$	$pred_2$.
High	(e)	RC_B	N_C $postp_1$	N_A $postp_2$	N_B topic	$pred_1$	$pred_2$.
Low	(f)	RC_C	N_C $postp_1$	N_A $postp_2$	N_B topic	$pred_1$	$pred_2$.
High	(g)	RC_A	N_B $postp_1$	N_C $postp_2$	N_A topic	$pred_1$	$pred_2$.
Low	(h)	RC_B	N_B $postp_1$	N_C $postp_2$	N_A topic	$pred_1$	$pred_2$.
Mid	(i)	RC_C	N_B $postp_1$	N_C $postp_2$	N_A topic	$pred_1$	$pred_2$.

Note: letter subscripts indicate attachment, so that RC_A plausibly attaches only to N_A, for example. Postp = postposition; topic = topic marker; pred = predicate.

Table 3.1: Regions for self-paced reading presentation.

initiated the locatives used as postpositions) mark the previous noun and are not used on their own. Second, the comparison between LexCat-parsing and PredCat-parsing is only possible if the partial information (i.e., the postposition predicting a higher noun) is available at the earliest possible point. For LexCat-parsing any such delay would not have any impact (as the parser is not taking partial information into account), but for PredCat-parsing a slight delay may disrupt the use of the information and could create a confound.

Nine lists were created by distributing the thirty-six stimuli in a Latin Square design. Each participant saw exactly one of the lists intermixed with 65 unrelated items in pseudo-random order. After each sentence, participants answered a yes/no comprehension question presented on a new screen.

3.1.3 Stimulus norming

A crucial assumption in this kind of experiment is that attachment to each of the three sites is equally grammatical. In particular, in the present case, it is necessary to guarantee that attachment of the RC to N_2 is grammatical by making sure that the first PP (N_3 $postp_1$) modifies N_2 (see Figure 3.1) and not N_1 (see Figure 3.2). In the latter structure, it would not be possible to attach the RC to N_2, assuming that attachments leading to crossing branches

in the tree structure are ungrammatical.

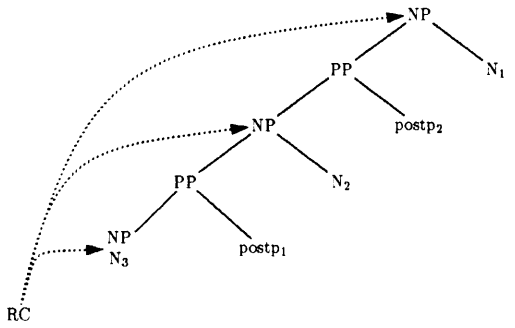

Figure 3.1: N_3 modifying N_2 — RC can attach to any of the 3 nouns.

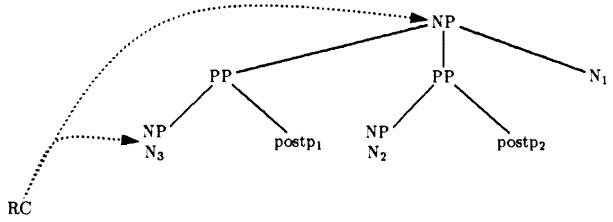

Figure 3.2: N_3 modifying N_1 — RC cannot attach to N_2.

To ensure that the PP containing N_3 is modifying N_2 and not N_1 in our stimuli, we presented a separate group of 46 native Japanese speakers with fragments like Example (4a) and questions about which of N_1 or N_2 was modified by N_3, as in Example (4b).

Example (4)

	N_A	$postp_1$	N_B	$postp_2$	N_C
a.	shigemi-no	yoko-no	hito-no	ushiro-no	jitensha
	bush	beside	person	behind	bicycle

"the bicycle behind the person beside the bush"

b. shigemi-no yoko-ni-wa hito-ga imasuka soretomo jitensha-ga arimasuka?
bush beside-Loc -Top person-Nom is or bicycle-Nom is?

"Is the person or the bicycle beside the bush?"

As in Table 3.1.2, each triple of head nouns was rotated through three different orderings, yielding a total of 108 ordered triples of nouns. Each participant saw exactly one of the orderings of each of the 36 triples mixed pseudo-randomly with 44 filler items. Some of the fillers were biased for low or high attachment and were used to ensure that participants were not using any particular strategy in the survey. Nine participants' data were eliminated for not answering these foil items appropriately.

As expected, participants had a strong preference for the low attachment, choosing to attach N_3 to the lower noun (N_2) more than 85% of the time. In each of the 36 triples, low attachment was preferred at least 75% of the time.

3.1.4 Procedure

The experiment was conducted on a Power Macintosh 7500/100 running Psyscope (Cohen, MacWhinney, Flatt & Provost, 1993). Participants were timed in a phrase-by-phrase self-paced non-cumulative moving-window reading task (Just, Carpenter & Woolley, 1982) controlled by a button-box. Stimuli initially appeared as dots, and participants pressed the leftmost button of the button-box to reveal each subsequent region of the sentence and cause all other regions to revert to dots. At the end of each sentence, a yes/no question appeared on a new screen, which participants answered by pressing one of two buttons. No feedback was given.

The experimental trials were preceded by one screen of instructions and eight practice trials. All sentences were presented on a single line. The experiment took participants approximately 20 minutes.

3.1.5 Analysis

We analyzed comprehension question response accuracy and reading times. For the purposes of analysis and presentation of the data, the nine sub-conditions in Table 3.1.2 were collapsed into the three conditions of interest (low, mid, high attachment).

Analyses were conducted on residual reading times per region (Ferreira & Clifton, 1986), derived by subtracting from raw reading times each participant's predicted time to read regions of the same length (measured in number of characters), which in turn was calculated from a linear regression equation across all of a participant's sentences in the experiment. The residual reading times were trimmed so that data points beyond four standard deviations from the relevant condition × region cell mean were discarded, corresponding to less than 1% of the total data. The means and analyses presented below are based on the trimmed residual reading times. The same patterns were present in the raw reading times. See Appendix 3-A for a graph of the raw reading times in each condition.

Two participants were eliminated for having unusual intercepts in their regression equations (1949 ms and -1505 ms). The other 36 participants had intercepts between 155 and 1008 ms (M = 524 ms; SD = 232 ms). Inclusion of the two participants eliminated did not alter the patterns in the data.

3.2 Results

3.2.1 Comprehension question response accuracy

Performance in the low attachment condition (91.2% correct) was better than in the middle (85.2%) ($F_1(1,35) = 8.51$, $p < 0.01$; $F_2(1,35) = 12.3$, $p < 0.01$) or the high (85.6%) conditions ($F_1(1,35) = 9.33$, $p < 0.01$; $F_2(1,35) = 8.23$, $p < 0.01$), but the high and middle conditions did not differ ($Fs < 1$).

3.2.2 Reading times

Figure 3.3 shows the residual reading times by region. No differences were detected (Fs < 1) in the first region (the RC). In region 2 (the first PP), the low attachment condition was significantly faster than the middle condition ($F_1(1,35) = 5.37$, $p < 0.05$; $F_2(1,35) = 5.67$, $p < 0.05$) and the high condition ($F_1(1,35) = 10.5$, $p < 0.01$; $F_2(1,35) = 7.87$, $p < 0.01$). The high and middle conditions did not differ (Fs < 1).

In region 3 (the second PP), the high condition was faster than the low condition ($F_1(1,35) = 13.2$, $p < 0.01$; $F_2(1,35) = 11.9$, $p < 0.01$) and the middle condition ($F_1(1,35) = 8.76$, $p < 0.01$; $F_2(1,35) = 10.2$, $p < 0.01$); but the low and middle conditions did not differ ($F_1(1,35) = 1.17$, $p = 0.287$; $F_2(1,35) = 1.21$, $p = 0.278$).

Region 4 (the third noun and the topic marker) presented the same pattern as region 3: the high condition was faster than the low condition ($F_1(1,35) = 9.76$, $p < 0.01$; $F_2(1,35) = 10.4$, $p < 0.01$) and the middle condition ($F_1(1,35) = 15.4$, $p < 0.01$; $F_2(1,35) = 19.2$, $p < 0.01$); and the low and middle conditions did not differ (Fs < 1).

In region 5 (the initial segment of the main predicate), the high condition was still faster than the low condition ($F_1(1,35) = 4.18$, $p < 0.05$; $F_2(1,35) = 4.34$, $p < 0.05$); but the middle condition did not differ from either the high condition ($F_1(1,35) < 1$; $F_2(1,35) = 1.06$) or the low condition ($F_1(1,35) = 1.55$, $p = 0.222$; $F_2(1,35) < 1$).

There were no differences in region 6 (the second part of the main predicate; Fs < 1).

Because the results of the norming study did not yield a 100% preference to attach the first PP low, it is possible that difficulty attaching the RC to the middle site could arise from the ungrammatical instances in which the first PP attached high. To ensure that our results were not due to these instances, analyses were also conducted upon the 12 items that, according to the off-line norming study, were most biased toward locally attaching the first PP. In those 12 items, the first PP attached low as desired an average of 92% of the time, with a minimum of 89% for any individual item. The numerical pattern of results for these items was identical to the pattern for the full set of stimuli. However, probably because of the small number of items in these analyses, the differences among the conditions in each region did not reach significance, except in region 4 (containing the high noun) where the

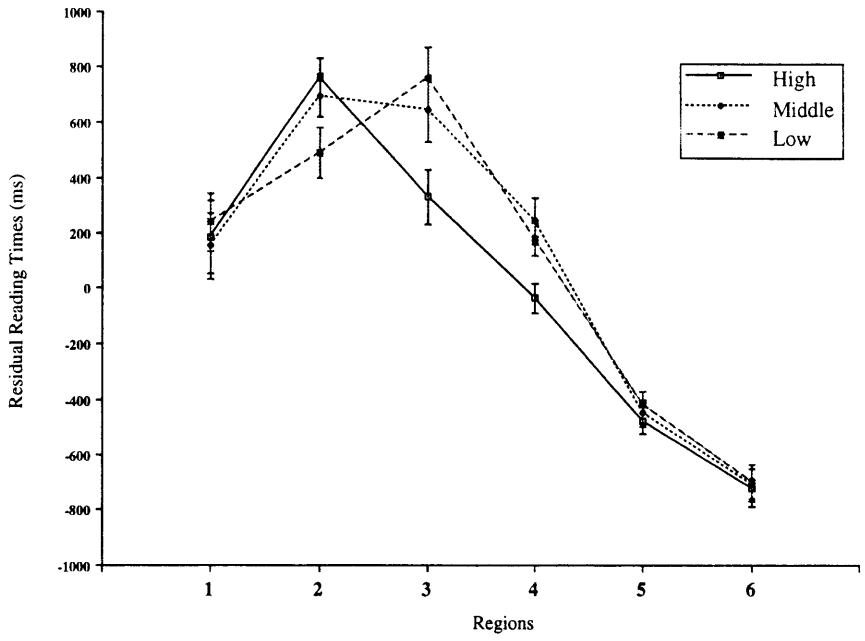

Figure 3.3: Residual reading times for each region.

high attachment condition was significantly faster than the middle condition ($F_1(1,35) = 8.83$, $p < 0.01$; $F_2(1,11) = 7.81$, $p < 0.05$) and the low condition ($F_1(1,35) = 4.41$, $p < 0.05$; $F_2(1,11) = 6.38$, $p < 0.05$), but the middle and low conditions did not differ ($Fs < 1$).

3.3 Discussion

The results of the experiment indicate a preference to attach according to locality. First, the percentage of correct responses to the comprehension questions supports the preference to attach the RC to the closest noun. Second, a preference for the closest site was detected in region 2 of the self-paced reading presentation (i.e., the first PP). Because region 2 included a head noun and a postposition together, participants were probably aware that another head noun was to follow. Thus, the slow reading times in this region in the middle and high conditions were due to a preference to attach to the most local noun. This pattern of results

is therefore similar to the initial low attachment preference observed by Kamide et al. (1997, 1998) in a construction with two potential attachment sites. (We analysed our data using raw reading times per character, which is the method used by Kamide and colleagues, and found the same overall pattern of results as in the analysis with residual reading times.)

The results also support a U-shaped over a monotonic preference ordering of the candidate sites, which argues against LexCat-parsing models in general, and parameterized head attachment (Konieczny et al., 1997) and the race model (Hemforth et al., in press, 1997) in particular. These models make the wrong prediction for not allowing predicted but not yet processed sites to be considered as candidates for modification. The evidence for the U-shaped preference curve comes from regions 3 and 4, where the reading time of the high condition was faster than in the middle condition. In region 3, in particular, the noun being read (N_2) is compatible with the RC in the middle condition but not in the high condition. Therefore, the fact that this region was read slower in the middle than in the high condition suggests that attaching the RC to the middle site (in the middle condition) is harder than failing to attach the RC to this site (in the high condition), which strongly indicates that the middle site is dispreferred.

The reading times of the high condition in regions 2 (containing the low noun) and 3 (containing the middle noun) are particularly informative because in both cases the RC in this condition is incompatible with the head noun being read, but it is only in region 2 that the high condition is slower than the low. This suggests that the relatively slow reading time in region 2 in the high condition is not caused by the incompatibility between the head noun and the RC alone, otherwise a similar slow reading time should have occurred in region 3 as well. It is conceivable then that participants are attempting to attach the RC to each of the three incoming heads, and that they are only slow when the attachment fails with a favoured site (N_3) and it is unproblematic when it fails at a less preferred site (N_2), as long as they are aware that another potential site is to come.

The U-shaped preference curve supports the view that locality is overridden and a higher site is preferred for attachment even though the head of this site is only going to be available later than the lower site. This supports a PredCat-parsing model, in which the preference to attach to the high site over the middle site is explained by an independent factor. The

anaphor resolution process could be such a factor as it is not bound to either LexCat- or PredCat-parsing. Another possibility for the factor preferring the high site is predicate proximity, as it favours the sites structurally closer to a predicate and remains neutral to the use of partial information during parsing.

Overall, we can account for the U-shaped result in our experiment by adapting the proposal in Gibson et al. (1996) for head-initial RCs with three potential heads, as follows. When processing the low site, the parser considers attaching the RC to the current noun (N_3 in Example (2), repeated below as Example (5)) as well as to the noun predicted by the first postposition. However, because of locality strength at this point, the closest site (N_3) is preferred. If the low attachment fails for some reason (because of plausibility in the present experiment), the parser processes the middle site and considers the present noun (N_2) and the newly predicted noun as possible candidates for attachment. At this point, the predicate proximity (or possibly anaphor resolution) bias is stronger than locality, making the parser prefer to attach the RC to the upcoming noun (N_1) based solely on the partial information provided by the second postposition.

Example (5) *head-final RCs*
RC N_3 postposition N_2 postposition N_1

An interesting result in the present experiment that was not predicted by any of the models that were considered is the slow reading times of the low condition in regions 3 and 4. Because the RC attachment was presumably successful in region 2 in the low attachment condition, the processing of the two ensuing regions should have been straightforward. We speculate that one explanation could stem from the types of interpretations involved when the RC is attached to the low noun N_3 as compared to the high noun N_1. Consider an English example in which the RC **that Mary likes** is attached to the high noun **bicycle**.

Example (6) The bicycle beside the boy [$_{RC}$that Mary likes] ...

Because **bicycle** is already being restricted by the PP **beside the boy**, it is less likely that the RC further restricts **bicycle** because, in order to do so, we would have to imagine several bicycles some of which are **beside the boy** and, among these **bicycles beside the boy**, it is the case that **Mary likes** one of them (as in Altmann & Steedman, 1988; Crain & Steedman, 1985). Thus,

restricting an already restricted entity in the discourse may lead to a level of complexity that the parser may not be willing to entertain in a null context. According to this reasoning, then, when attached high, the RC is more likely to be interpreted as providing some extra (non-restrictive) information about the noun. However, if the RC modifies the low noun boy, then a restrictive interpretation of the RC may obtain. Suppose that this is what is happening in the Japanese head-final RC construction: the RC is sometimes interpreted as restrictive in the low attachment, but always as non-restrictive in the other attachments. In this case, if discourse is more complex for restrictive than non-restrictive information, the low attachment of the RC might have been particularly taxing in regions 3 and 4 as the complexity of the restrictive RC was compounded with the complexity of modifying N_2 with N_3 and then N_1 with N_2 according to the intervening postpositions. Therefore, in the low condition, the initial advantage from locality in region 2 would be replaced by difficulty with discourse complexity in the following two regions. It is unlikely that discourse complexity is the factor favouring the high site overall because, according to the previous reasoning, the middle attachment would also lead to a non-restrictive interpretation of the RC and therefore this hypothesis could not explain the advantage of the high over the middle condition in regions 3 and 4. See Kamide et al. (1997, 1998) for a similar slow reading time after the low attachment is made.

Kamide and colleagues suggested a different explanation for the relative slow reading times after the attachment is made in the low condition. They proposed that the longer the RC, the more likely it will be re-attached to the high noun. Supporting evidence comes from a positive correlation between the length of the RC and the difference between the reading times of the low and the high conditions in their self-paced reading experiment (Kamide et al., 1998). In our experiment, the relatively slow reading times in regions 3 and 4 in the low condition could be due to a late preference that the parser may have to re-attach longer RCs to the high site. If this were the case, longer RCs in the present experiment should lead to greater slow-downs. However, in our data, no correlation was found between the number of characters in the RC and the reading times of the low condition in region 2 ($r = -0.06$; $p = 0.53$), region 3 ($r = -0.12$; $p = 0.22$) or region 4 ($r = -0.01$; $p = 0.91$). The analysis was conducted taking the low subconditions in Table 3.1.2 (namely, (a), (f)

and (h)) separately, because the RCs in these subconditions had different lengths. Similarly, no correlation was found between RC length and the difference in reading times of the low and high conditions in region 2 (r = -0.04; p = 0.67), region 3 (r = -0.01; p = 0.87) or region 4 (r = -0.04; p = 0.68). The differences in residual reading times were calculated separately for the subconditions in Table 3.1.2 as follows: a–g, f–c and h–e. It is unlikely that the correlations were not significant because too few data points were considered. Each of the two correlation analyses above was conducted with a total of 107 pairs of points (i.e., three subconditions times 36 items, except for one item that had no data available for one subcondition), with the length of the relative clauses varying between 4 and 17 characters (M = 9.6; SD = 2.9). Moreover, comprehension performance was best in the low condition, which does not support a re-attachment explanation, because more confusion (and hence more comprehension errors) might be expected if such re-attachments had been attempted.

3.4 Conclusion

There seem to be two factors at work in the Japanese head-final RC construction with multiple candidate hosts. One is locality favouring the closest site, the other (possibly predicate proximity or anaphor resolution) favours the high site and hence the U-shaped preference curve. On top of these two factors, we tentatively suggest that discourse complexity may also play a part as the type of interpretation for the RC varies.

The U-shaped preference ordering of the candidate sites in the present head-final construction is particularly informative because it supports a parsing framework in which predicted categories are also considered as candidates for attachment even if lexically-realized alternatives may already be available during the processing of the construction. We have argued that such use of partial information is crucial to explain the preference attachment to the high site over the middle site, and that any model of modifier attachment must be able to accommodate such a feature in order to account for the preference ordering observed here.

Appendix 3-A.

The raw reading times (i.e., without normalizing according to length), trimmed at 4.0 standard deviations (calculated for each condition), are shown in Figure 3.4.

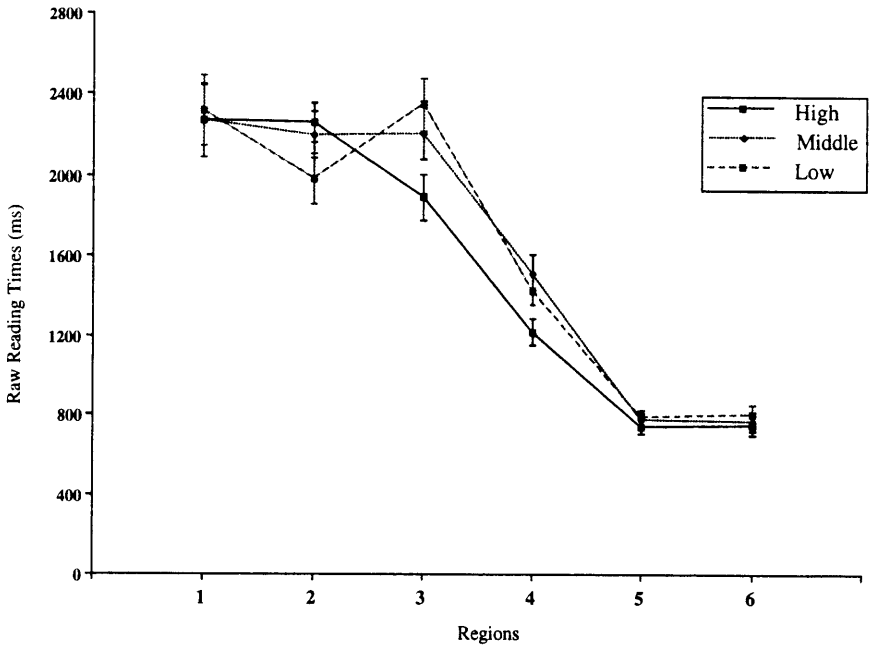

Figure 3.4: Raw reading times for each region.

Appendix 3-B.

The following are the experimental items used in the experiment. All nine subconditions are presented for item 1. For all the other items, only three subconditions are presented as the other six subconditions can be deduced from the pattern presented in Table 3.1.2.

The following were the 12 items that were also analysed separately because they were the most biased towards locally attaching the first PP, according to the off-line norming study: 10, 11, 13, 14, 16, 21, 22, 24, 32, 33, 34 and 35.

1a. 夕べほえていた 机の横の ドアの近くの 犬は、 毛むくじゃらで
濡れている。
1b. ノブがこわれている 机の横の ドアの近くの 犬は、 毛むくじゃらで
濡れている。
1c. 上の引き出しが壊れている 机の横の ドアの近くの 犬は、 毛むくじゃらで
濡れている。
1d. 夕べほえていた ドアの横の 犬の近くの 机は、 英国製の アンティークだ。
1e. ノブがこわれている ドアの横の 犬の近くの 机は、 英国製の
アンティークだ。
1f. 上の引き出しが壊れている ドアの横の 犬の近くの 机は、 英国製の
アンティークだ。
1g. 夕べほえていた 犬の横の 机の近くの ドアは、 いい鍵がついていて
盗難を防ぐ。
1h. ノブがこわれている 犬の横の 机の近くの ドアは、 いい鍵がついていて
盗難を防ぐ。
1i. 上の引き出しが壊れている 犬の横の 机の近くの ドアは、 いい鍵がついていて
盗難を防ぐ。

2a. その中にほうきがしまってあった 皿洗機の右側の こんろの反対側の 戸棚は、
引き出しが三段ついていて かなり幅がある。
2e. 野菜を調理していた こんろの右側の 戸棚の反対側の 皿洗機は、
昨日デパートで 買った。
2i. 今、皿を洗っている 戸棚の右側の 皿洗機の反対側の こんろは、
昨日デパートで 買った。

3a. 私が夕べ読んだ 鉛筆の近くの ディスケットの右側の 本は、 長くて
退屈だった。
3e. 私が夕べ消した ディスケットの近くの 本の右側の 鉛筆は、 教室に あった。
3i. 私がしんを折ってしまった 本の近くの 鉛筆の右側の ディスケットは、 便利で
仕事が捗った。

4a. きのうの消印が押された 缶の左側の ホッチキスの前の 絵葉書は、 小さくて
奇麗だった。
4e. 針が入っていなかった ホッチキスの左側の 絵葉書の前の 缶は、 ひ
ょろ長くて 滑り易い。
4i. コカコーラが一杯入っていた 絵葉書の左側の 缶の前の ホッチキスは、 重くて
黒い。

5a. 山田さんが群集に砲火した 鍵の隣の ズボンの後ろの 銃は、 本物の弾が
入っていた。
5e. 椅子でひっかけてやぶってしまった ズボンの隣の 銃の後ろの 鍵は、 鋭くて
ギザギザだった。
5i. 山田さんがきのう金物屋で買った 銃の隣の 鍵の後ろの ズボンは、 茶色で
短すぎた。

6a. きのう巣を作っていた 水たまりの横の 小枝の隣の クモは、 小さいが
恐い。
6e. 木から折れて落ちてしまった 小枝の横の クモの隣の 水たまりは、 深くて
大きかった。
6i. 子供がピチャピチャ水を飛び散らした クモの横の 水たまりの隣の 小枝は、
曲がっていて 脆かった。

7a. とてもうるさく鳴っていた ペンの近くの コップの左の 電話は、 軽くて
使い易い。
7e. 水がこぼれ落ちそうに入っている コップの近くの 電話の左の ペンは、 古いが
とてもよく書ける。
7i. インクがきれている 電話の近くの ペンの左の コップは、
蝋が入っていて 壊れている。

8a. 羽毛が一杯つまった　　ベルトの右側の ナイフの反対側の 枕は、
ふかふかしていて 心地よい。
8e. 鋭く尖れた　　ナイフの右側の 枕の反対側の ベルトは、
擦り切れていて 小さい。
8i. いつも川野さんがズボンにしている 枕の右側の ベルトの反対側の ナイフは、
切れ味が 悪い。

9a. すごいスピードで走っていた 道路の横の 標識の前の バスは、 明るい黄色で
とても長かった。
9e. 読みにくかった　　標識の横の バスの前の 道路は、 狭くて カーブが多い。
9i. 車が止めてあった　　バスの横の 道路の前の 標識は、 古くて
雨や風で傷んでいる。

10a. ページが破れている　ラジオの近くの コンピューターの隣の 雑誌は、
三十年前のものだが まだそのまま保存されている。
10e. 画面が緑の　　コンピューターの近くの 雑誌の隣の ラジオは、 楽しませて
リラックスさせてくれる。
10i. 五つの放送局が聞ける 雑誌の近くの ラジオの隣の コンピューターは、 便利で
面白い。

11a. その部屋を照らしていた　ステレオの右側の ソフアの後ろの ランプは、
煌々として 高い。
11e. 座り心地よいクッションの ソフアの右側の ランプの後ろの ステレオは、
音が大きくて 耳障りだ。
11i. うるさい音でなっていた　ランプの右側の ステレオの後ろの ソフアは、
柔らかいが 丈夫だ。

12a. 夕べ一晩中鳴いていた　蝶の近くの 花の前の カエルは、 とても機敏で
すばしっこい。
12e. 五月に満開に咲いていた 花の近くの カエルの前の 蝶は、 そよ風の中を
ひらひらと飛んでいる。
12i. さなぎから出たばかりの カエルの近くの 蝶の前の 花は、 鮮やかで
色彩に富んでいる。

13a. 素晴らしい曲を弾いた　　子猫の横の 椅子の左の ギターは、 木製で
美しい音色を出す。
13e. 脚にキャスターが付いている 椅子の横の ギターの左の 子猫は、 毛
がフサフサしていて 愛らしい。
13i. 毛糸玉とじゃれている　　ギターの横の 子猫の左の 椅子は、 柔らかくて
座り心地がよい。

14a. ハスの葉が浮いていた　　道の前の 家の右側の 池は、 風で 波立っている。
14e. 古れんがでできた煙突がある 家の前の 池の右側の 道は、
くねくねと曲がっていて 狭い。
14i. 平野さんが歩き慣れた　　池の前の 道の右側の 家は、 朽ちて
倒れかけていた。

15a. 中村さんが木曜日にしていた　ほうきの左の ティーポットの後ろの
エプロンは、 汚れていて シミが付いている。
15e. ストーブの上で沸き立っていた ティーポットの左の エプロンの後ろの ほうきは、
ブラシは硬いが 使い易い。
15i. 中村さんが床を掃いた　　エプロンの左の ほうきの後ろの
ティーポットは、 日本製で 美味しいお茶がいれられる。

16a. 自分の鳴き声で犬を追い立てた 帽子の近くの 靴の反対側の 猫は、 年寄りで
愛想が悪い。
16e. 私が右足にはいていた　　靴の近くの 猫の反対側の 帽子は、
上に大きな羽が 付いている。
16i. 私が頭にかぶっていた　　猫の近くの 帽子の反対側の 靴は、
キメの細かい革で できている。

17a. 自分の父親に微笑みかけた　　ベッドの隣の ボールの前の 男の子は、
優しくて 朗らかだ。
17e. その子供が池に投げすてようとした ボールの隣の 男の子の前の ベッドは、
寝心地がよくて 小さい。
17i. 犬が寝ていた　　男の子の隣の ベッドの前の ボールは、 ゴム製で
よく弾む。

18a. マリーがパイのために切った　手紙の近くの スプンの後ろの りんごは、
つるつる光っていて 赤い。
18e. マリーがヨーグルトをすくった スプンの近くの りんごの後ろの 手紙は、
長くて 詳しく書かれている。
18i. マリーがけさ叔父宛に書いた　りんごの近くの 手紙の後ろの スプンは、
歯が入っていて 欠けている。

19a. 観光客に噛みついた プールの隣の 柵の左側の ライオンは、 大きくて
美しい。
19e. 鎖で出来ている 柵の隣の ライオンの左側の プールは、 大きくて
美しい。
19i. 観光客が泳いだ ライオンの隣の プールの左側の 柵は、 大きくて
美しい。

20a. 学校まで乗った 茂みの横の 人の後ろの 自転車は、 きれいで 大きかった。
20e. パーティーで会った 人の横の 自転車の後ろの 茂みは、 きれいで 大きかった。
20i. 枝がおれている 自転車の横の 茂みの後ろの 人は、 きれいで 大きかった。

21a. 妹が描いた テーブルの隣の テレビの右側の 絵は、 高くて
小さかった。
21e. うるさい音がしている テレビの隣の 絵の右側の テーブルは、 高くて
小さかった。
21i. 私が夕べ食事をした 絵の隣の テーブルの右側の テレビは、 高くて
小さかった。

22a. お茶がいっぱい入っている 写真の横の 新聞の反対側の 茶碗は、 古くて
黄ばんでいた。
22e. うその話が書いてある 新聞の横の 茶碗の反対側の 写真は、 古くて
黄ばんでいた。
22i. 昨日焼き増しした 茶碗の横の 写真の反対側の 新聞は、 古くて
黄ばんでいた。

23a. ワインを急冷凍した 缶切りの隣の 流しの左側の 冷蔵庫は、 古くて
使いにくかった。
23e. 我々が食器洗いをした 流しの隣の 冷蔵庫の左側の 缶切りは、 古くて
使いにくかった。
23i. 研ぐ必要のある 冷蔵庫の隣の 缶切りの左側の 流しは、 古くて
使いにくかった。

24a. 木に登った 街灯の隣の 郵便受けの反対側の りすは、 小さくて
可愛かった。
24e. 郵便やさんがあけた 郵便受けの隣の りすの反対側の 街灯は、 小さくて
可愛かった。
24i. 道を明るく照らしている りすの隣の 街灯の反対側の 郵便受けは、 小さくて
可愛かった。

25a. 女の子にささやいた コピー機の近くの 壁の横の 図書館員は、 大きくて
醜かった。
25e. コンクリートで出来ている 壁の近くの 図書館員の横の コピー機は、
大きくて 醜かった。
25i. 私が以前論文を複写した 図書館員の近くの コピー機の横の 壁は、
大きくて 醜かった。

26a. 清掃婦がほうきではいた アライグマの後ろの バケツの反対側の 砂は、
茶色で きれいだった。
26e. 水がいっぱい入っている バケツの後ろの 砂の反対側の アライグマは、
茶色で きれいだった。
26i. 追いかけた 砂の後ろの アライグマの反対側の バケツは、 茶色で
きれいだった。

27a. 警笛を吹いた 車の横の 木の右側の 警察官は、 美しくて 有名だった。
27e. 葉っぱが落ちてしまった 木の横の 警察官の右側の 車は、 美しくて
有名だった。
27i. バックミラーがとれている 警察官の横の 車の右側の 木は、 美しくて
有名だった。

28a. 弦が切れた スツールの左側の トランペットの前の ハープは、 古くて
小さかった。
28e. 吹き口がなくなった トランペットの左側の ハープの前の スツールは、 古くて
小さかった。
28i. 花子がすわった ハープの左側の スツールの前の トランペットは、 古くて
小さかった。

29a. 田中さんに書いた 鏡の横の 練り歯磨きの反対側の メモは、 新しくて
白かった。
29e. 虫歯を防ぐ 練り歯磨きの横の メモの反対側の 鏡は、 新しくて
白かった。
29i. 光っている メモの横の 鏡の反対側の 練り歯磨きは、 新しくて
白かった。

30a. まだ飲んでいない　スプーンの後ろの　ステーキの近くの　お茶は、　高くて
有名だ。
30e. こんがりと焼いてある　ステーキの後ろの　お茶の近くの　スプーンは、　高くて
有名だ。
30i. 銀で出来ている　お茶の後ろの　スプーンの近くの　ステーキは、　高くて
有名だ。

31a. ヒールが高い　上着の隣の　傘の右側の　ブーツは、　古くて　破れていた。
31e. 柄が奇麗な　傘の隣の　ブーツの右側の　上着は、　古くて　破れていた。
31i. いい生地で出来ている　ブーツの隣の　上着の右側の　傘は、　古くて
破れていた。

32a. 消えてしまった　バラの前の　彫像の左側の　ローソクは、　大きくて
きれいだった。
32e. 腕が一本おれている　彫像の前の　ローソクの左側の　バラは、　大きくて
きれいだった。
32i. きれいに咲いている　ローソクの前の　バラの左側の　彫像は、　大きくて
きれいだった。

33a. はさみが一つしかない　タオルの近くの　ビンの前の　カニは、　小さくて
赤かった。
33e. コーラが入っている　ビンの近くの　カニの前の　タオルは、　小さくて
赤かった。
33i. 洗濯した　カニの近くの　タオルの前の　ビンは、　小さくて　赤かった。

34a. くぎを打った　鋸の横の　ドライバーの後ろの　カナズチは、　新しくて
使いやすかった。
34e. ネジをしめた　ドライバーの横の　カナズチの後ろの　鋸は、　新しくて
使いやすかった。
34i. 板を切った　カナズチの横の　鋸の後ろの　ドライバーは、　新しくて
使いやすかった。

35a. ガットのはりかえが必要な　ロッカーの前の　トレーナーの右側の　ラケットは、
新しくて　高かった。
35e. 袖が長い　トレーナーの前の　ラケットの右側の　ロッカーは、
新しくて　高かった。
35i. 鍵がかかっている　ラケットの前の　ロッカーの右側の　トレーナーは、
新しくて　高かった。

36a. 10分おくれている　マグカップの隣の　カタログの反対側の　時計は、
高くて　重かった。
36e. ２００ページもある　カタログの隣の　時計の反対側の　マグカップは、
高くて　重かった。
36i. コーヒーが入っている　時計の隣の　マグカップの反対側の　カタログは、
高くて　重かった。

Chapter 4

Future directions

As described in Chapter 2, relative clause (RC) attachment requires some parametric factor to be determined in order to explain the distinct preferences observed across languages. However, as seen in Chapter 3, cross-linguistic variations aside, RC attachment ambiguities are also interesting because they can be used to investigate properties of the human parser that may not be easily observable in other constructions. Two factors contribute to make RCs particularly suitable to test the types of factors to which the human parser is susceptible. First, RCs allow for a number of factors to be readily manipulated. Moreover, when not constrained by grammatical features (such as number or gender agreement) or by plausibility, RC attachment tends to have a weak bias for one of the available candidate sites, which can thus be overriden when appropriate features are manipulated.

The two sections in this chapter describe two on-going projects that take advantage of RC attachment ambiguities in order to explore general properties of the cognitive mechanisms underlying language processing.

4.1 Gender mismatch

The investigation of relative clause (RC) attachment as initiated by Cuetos & Mitchell (1988) led to the uncovering of a number of interesting phenomena (see Cuetos, Mitchell & Corley, 1996, for a recent overview). The present section reports a processing difficulty caused by a local gender mismatch. This result has precedents in the work of Sauerland & Gibson (1997),

who proposed that native German speakers prefer the case marking on a relative pronoun to be the same as on the noun that the RC modifies, even when the grammar itself does not impose such case matching constraints, as in the following sentences.

Example (1)

a. *Local case matching*
Der Brief ist für den Produzenten des Musikers [$_{RC}$ dessen Bein verletzt ist].
The letter is for the producer$_{\underline{Acc}}$ of musician$_{\underline{Gen}}$ whose$_{\underline{Gen}}$ leg injured is]
"The letter is for the producer of the musician whose leg is injured."

b. *Non-local case matching*
Der Brief ist für den Produzenten des Musikers [$_{RC}$ den eine Beinverletzung vom Kommen abhielt].
The letter is for the producer$_{\underline{Acc}}$ of musician$_{\underline{Gen}}$ who$_{\underline{Acc}}$ a leg-injury from happening prevented.
"The letter is for the producer of the musician who prevented a leg injury from happening."

c. *No case matching*
Der Brief ist für den Produzenten des Musikers [$_{RC}$ der am Bein verletzt ist].
The letter is for the producer$_{\underline{Acc}}$ of musician$_{\underline{Gen}}$ who$_{\underline{Nom}}$ at the leg injured is.
"The letter is for the producer of the musician who is injured in the leg."

The sentences in Example (1) are ambiguous in that the RC can modify either the local noun (**musician**) or the non-local noun (**producer**). However, because case marking on the relative pronoun matches the local noun in Example (1a), the non-local noun in Example (1b) and neither noun in Example (1c), Sauerland and Gibson predicted that RC attachment would be biased towards the local noun in (a) and towards the non-local noun in (b), whereas (c) should provide a baseline preference. The predictions were only partially obtained in these authors' off-line judgement study, in which native German speakers attached the RC to the local noun more often (73%) in (a) than in (b; 61%) and (c; 62%). But the difference in attachment preference between (b) and (c) was not statistically significant, which may suggest that the structural bias to attach the RC locally is too strong for case-matching in (b) to override.

Sauerland and Gibson's results raise three questions. First, the overall local attachment preference observed in their study contrasts with previous results in which a non-local attachment bias was detected in eye-tracking experiments with similar German RC constructions (Hemforth, Konieczny & Scheepers, in press). Second, although these authors only consider case marking, it is conceivable that the phenomenon at hand may extend to other types of feature matching. Third, there may be an alternative explanation for the phenomenon

observed, namely, that only feature mismatch between adjacent constituents interferes with attachment, hence the lack of non-local attachment preference in Example (1b). The purpose of this section is to investigate the last two questions by conducting an on-line experiment with RCs in Brazilian Portuguese (BP) in which gender is the feature manipulated.

4.1.1 Gender agreement in RC attachment

As in the English translation, the RC in the following sentence in BP can be attached to either of the underlined nouns. However in BP, the relative pronoun **whose**$_{masc}$ has to agree in number and gender with the ensuing noun **shoe**$_{masc}$, but not with the noun that the RC modifies (**lawyer**$_{fem}$ or **prisoner**$_{fem}$).[1]

Example (2)

A	advogada	da	prisioneira	[$_{RC}$ cujo	sapato	estava	sujo]	conversou com o juiz.
the	lawyer$_{fem}$	of	prisoner$_{fem}$	whose$_{masc}$	shoe$_{masc}$	was	dirty$_{masc}$	talked to the judge

"The lawyer of the prisoner whose shoe was dirty talked to the judge."

If there is a generalized tendency for the human parser to match features on a head noun with the features on the relative pronoun, then by manipulating gender on the head nouns (**lawyer** and **prisoner**) and on the relative pronoun, it should be possible to bias the attachment preference accordingly, even though there is no requirement for such gender matching in the grammar. However, if Sauerland and Gibson are correct and only case features are matched, then there should be no difference in attachment because the relative pronoun used will always have genitive case and hence it should always favour attachment to the local site, which also has genitive case. Note that in BP, as in English, case is usually not morphologically realized on noun phrases.

4.1.2 Method

The items in the present experiment were used as fillers for the experiment reported in Chapter 2, hence the participants, the procedure and the residual reading time analysis were

[1]The subscripts for feminine (fem) and masculine (masc) are only used if the BP word is inflected for gender but the corresponding English word does not indicate it.

as described previously.

Materials

There were three conditions as follows. (The two head nouns are underlined and the relative pronoun is in italics.)

Example (3)
a. *Matching both sites*
O advogado do prisioneiro *cujo* sapato estava sujo de barro conversou demoradamente com o juiz.
"The lawyer$_{masc}$ of the prisoner$_{masc}$ whose$_{masc}$ shoe was soiled with mud talked for a long time with the judge."
b. *Local matching*
A advogada do prisioneiro *cujo* sapato estava sujo de barro conversou demoradamente com o juiz.
"The lawyer$_{fem}$ of the prisoner$_{masc}$ whose$_{masc}$ shoe was soiled with mud talked for a long time with the judge."
c. *Non-local matching*
O advogado da prisioneira *cujo* sapato estava sujo de barro conversou demoradamente com o juiz.
"The lawyer$_{masc}$ of the prisoner$_{fem}$ whose$_{masc}$ shoe was soiled with mud talked for a long time with the judge."

In Example (3a), the relative pronoun is masculine and matches both local and non-local head nouns. In Example (3b), the relative pronoun matches only the local noun, while in Example (3c), it matches only the non-local noun. Number was kept singular in all relevant constituents.

As observed earlier, if only case features are matched in RC attachment, then the three conditions should not differ in attachment pattern. However, if gender matching has the same effect as case matching, then the RC should attach locally more strongly in Example (3b) than in Example (3c). Moreover, if only the gender on the adjacent noun matters, then Example (3a) should pattern as (b). However, if gender on the non-local noun also influences the outcome, then the non-local attachment should be stronger in (a) than in (b).

After each sentence, a comprehension question was presented querying about the attachment of the RC. No feedback was given in this experiment because both attachments are grammatical. This task would most closely resemble the judgement task in Sauerland &

Gibson (1997). Moreover, residual as well as raw reading times were also analysed according to the attachment preference expressed in the comprehension question. For purposes of analysis only, the sentences were divided into three regions: region 1 contains the first four words (up to the local noun), region 2 contains the entire RC and the main verb (words 5 to 11), and region 3 contains the final words in the sentence. The crucial region for analysis was region 2.

There were a total of twelve items. In six items, the relative pronoun had masculine marking and in the other six, feminine marking. Each participant saw four items for each matching condition in a Latin Square design, intermixed with 82 unrelated items in pseudo-random order.

4.1.3 Results

Answers for the questions presented the following results. The local attachment preferences in the both-matching, local-matching and non-local-matching conditions were 62%, 64% and 67% respectively and did not differ significantly (Fs < 1).

The raw reading times presented the same numerical pattern as the residual reading times and will not be discused further.

The results for the analyses with residual reading times were conducted as a 2 by 3 design: attachment site (local or non-local) and matching condition (both-matching, local-matching and non-local-matching). Note that the attachment site condition was based on each participant's response to the comprehension question, hence, the analysis by subjects could not be carried out as some participants consistently chose one attachment site for a given matching condition, thus not presenting data for the other attachment site. In region 1 and region 3, there was no interaction between attachment site and the matching conditions ($F_2 < 1$). In region 2, the interaction was significant ($F_2(2,22) = 3.77$, $p < 0.05$), which is due to the non-local attachment condition being significantly slower than the local attachment condition for non-local matching ($F_2(1,11) = 5.75$, $p < 0.05$) but not in the other two matching conditions ($F_2 < 1.7$).

No significant difference was observed between the items with feminine or masculine

relative pronoun ($F_2 < 1$).

4.1.4 Discussion

The reading time results suggest that the gender of the local noun may be the main cause for the interaction observed. In the both-matching and local-matching conditions, the local-noun gender matches the relative pronoun, and the reading times of the two conditions did not differ. In the non-local matching condition however, the local noun does not match the gender of the relative pronoun and here a significant slow-down is observed when the RC is attached to the non-local noun. The influence of the local noun would be further supported if a fourth condition, missing in the present experiment, in which neither noun matches the relative pronoun gender, also yielded a slow-down similar to the one observed in the non-local matching condition.

If supported by future work, intrusion of the local feature in the attachment of the RC to the non-local noun raises a rather interesting question, namely, why is the parser hindered by the mismatch of features which the grammar does not require to be matched. Moreover, considering grammar formalisms in which features are percolated along the structural organization of a sentence (e.g. Gazdar, Klein, Pullum & Sag, 1985), the features involved in the present case are not required to be matched by the grammar, but more importantly, they may not be matched. Note that the slow-down is observed when the RC is attached to the non-local noun, hence percolating the features from the local noun to the relative pronoun does not respect the structural relations of the components in the sentence.

This effect of a local feature mismatch is also observed when the agreement of a singular head noun and a verb is disrupted by an intervening plural noun (Bock & Miller 1991). But the comparison with the present result should be made with caution because the result with number was in a production task, while here the claim is about the comprehension stage.

Future work should also address the lack of effect of gender mismatch on attachment preference in the comprehension question response in contrast to the result obtained by Sauerland & Gibson (1997). Two possible explanations can be entertained at this point. First, case marking may interfere more strongly in parsing than gender features. Second,

the internal structure of the RCs used by Sauerland and Gibson varies from condition to condition, hence possibly being an extra source for the attachment differences they observed.

4.2 Articulatory suppression

The present section is an attempt to bring three independent lines of research together. First, there have been recent proposals that during silent reading native speakers compute prosodic contours which in turn influence the way ambiguities are resolved (Bader, 1998; Fodor, 1998). Although plausible, evidence for such claims has been indirect by providing effects that are likely to derive from such implicit prosody, but no attempts have been made to show that prosodic contours are indeed computed during silent reading. A second line of research compared reading time patterns of two groups of native speakers, which were divided according to an independent memory span task, and its conclusion was that ambiguity resolution is affected by the amount of short term memory available during parsing (King and Just, 1991). Finally, within the working memory model, Baddeley and colleagues have shown that phonological effects (e.g., the phonological similarity effect and word length effect) in the recall of lists of words are eliminated when participants have to simultaneously perform a secondary task in which the articulatory loop is suppressed as participants continuously pronounce an irrelevant syllable (see Baddeley, 1990 for an overview; Coltheart, Avons & Trollope, 1990 for elimination of homonym effects during reading). Moreover, articulatory suppression has also been shown to decrease the amount of short-term memory available as participants recall fewer words when required to pronounce nonsense syllables at the same time.

Hence, given that articulatory suppression eliminates phonological effects (and possibly any prosodic effects as well) and decreases overall short-term memory available, then, according to the implicit prosody and the memory span proposals, articulatory suppression should also interfere with ambiguity resolution. Of particular interest here is the claim that differences in prosodic contours are responsible for relative clause attachment preferences observed across languages (Fodor, 1998). More concretely, consider the following sentence in Spanish.

Example (4) (Adapted from Gibson, Pearlmutter & Torrens, in press.)
Un alumno insultó a los professores de las clases [$_{RC}$ que no gustaron a los estudiantes].
"A pupil insulted the professors of the classes that were not fancied by the students."

As discussed in Chapters 2 and 3, in constructions such as Example (4), native Spanish speakers prefer to attach the RC to the non-local noun (Cuetos & Mitchell, 1988; Gibson, Pearlmutter & Torrens, in press). If this attachment preference is due to the prosodic contours of this language, then articulatory suppression should affect the attachment pattern by either eliminating the preference altogether or by reverting attachment to the local site assuming that a locality effect may then be revealed. A crucial assumption here is that prosody is computed during silent reading through inner speech (Slowiaczek & Clifton, 1980), which presumably involves the articulatory loop.

In order to test this hypothesis, a self-paced reading experiment with a within-subject design is being conducted. In half of the trials, native Spanish speakers are required to pronounce irrelevant syllables ("ba" or "ta"), and in the other half they read silently. Order of the tasks is counterbalanced, thus half of the subjects read silently first, and the other half read while articulating in the first part of the experiment.

Initial results suggest that an interaction between articulation and attachment site takes place with the local attachment condition being read faster with simultaneous articulatory suppression. If this pattern of results is confirmed, this would be strong evidence that prosody is indeed being computed during silent reading. However, even in this case, interpretation of the result should be with caution as an alternative explanation may exist in that articulatory suppression decreases the amount of working memory available, therefore, potentially making the high site less available for attachment in the articulated condition.

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