Sentence Processing in Chinese and Chinese-English Bilinguals: Syntax-Semantics Interaction During Syntactic Ambiguity Resolution

by

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Dedication

This dissertation is dedicated to my parents, my brothers, and to Yih-fan Chen, for their

endless support and encouragement.

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Abstract

Four reading-time studies in the dissertation investigated the online representation of a syntactic ambiguity and the nature of the time course of the interaction between syntactic and non-syntactic constraints. The target syntactic ambiguity was the construction of *Verb NP$_1$ de* NP$_2$ in Chinese, which is ambiguous between a relative clause (RC) and a complement clause (CC) analysis.

Using an eye-tracking paradigm, Experiments 1 and 2 explored whether the parser can maintain multiple alternative structures of an ambiguity and how semantic plausibility influences the early stage of syntactic processing. The results demonstrated that the degree of processing difficulty at the disambiguation varied as a function of the relative support for the RC and the CC alternatives from the syntactic and the semantic constraints. The findings can be best accounted for by a limited, ranked parallel parsing model, such as the surprisal theory (Hale, 2001), which maintains that processing difficulty is incurred by resource reallocation during disambiguation.

Experiments 3 and 4 utilized syntactic priming to investigate how recent prior experience with a particular structure can influence syntactic ambiguity resolution in comprehension. Experiment 3 showed that lexically independent priming in comprehension facilitated the accessibility of the repeated RC structure, increasing the difficulty of structural revision to the unprimed CC alternative. Experiment 4 found that prior experience with the English RC structure affected the processing of the corresponding structure in Chi-

nese, even though the RC structures differ in word order in the two languages. The observed syntactic priming in comprehension between Chinese and English RC structures suggested that the two languages have a shared syntactic representation that does not specify word order.

Overall, the dissertation contributes to the understanding of structural representation and information integration during syntactic ambiguity resolution. The findings provided evidence for an interactive and limited parallel approach to sentence processing. Moreover, lexically independent comprehension priming suggested that prior experience with a particular syntactic configuration can function as a constraint at the structural level. Thus, a traditional constraint-based lexicalist theory (e.g. MacDonald, Pearlmutter, & Seidenberg, 1994) must incorporate non-lexical representations in order to make use of statistical regularities beyond the lexical level.

Chapter 1

Introduction

1.1 Background and Motivation

A central issue in sentence processing is how the human parser resolves syntactic ambiguity while reading or listening to sentences. Syntactically ambiguous regions are common across human languages, as is the experience of a "garden path"—i.e., processing difficulty associated with disambiguation toward a less preferred meaning (e.g., Bever, 1970). Garden path effects suggest that we often commit to an analysis while the structure is still ambiguous. Moreover, research clearly shows that the parser quickly uses semantic information and real-world knowledge in order to access the correct meanings of words and the appropriate syntactic and semantic relationships among them (e.g. Frazier & Clifton, 1996; Tanenhaus et al., 1995). Meanwhile, recent prior experience with a particular structure can influence syntactic ambiguity resolution in comprehension subsequently (e.g. Tooley et al., 2009; Thothathiri & Snedeker, 2008). That is, the processing of the previously encountered structural alternative can be facilitated during the ambiguous region. However, there is not yet a conclusive picture with respect to the online representation of a syntactic ambiguity and the nature of the time course of the interaction between syntactic and non-syntactic constraints. Furthermore, it is not clear if experience-based syntactic facilitation can persist across sentences with no lexical over-

lap or in different languages. In terms of bilingual syntactic ambiguity resolution, it is necessary to better understand how the different languages of bilinguals may influence each other during processing. In particular, does prior use of one language affect the accessibility of alternative interpretations of a syntactic ambiguity in the other language? The dissertation focuses on syntactic processing during monolingual and bilingual sentence comprehension.

In monolinguals, it has been shown that human sentence processing involves integrating a variety of knowledge sources in order to incrementally discriminate the preferred interpretation of a sentence. Considerable debate, however, has surrounded the issues of parallelism and encapsulation (Altmann, 2006). First, does the parser pursue only one structure at a time or does it maintain possible analyses in parallel during the ambiguous region? Second, does the parser use non-syntactic cues at the same time as syntactic cues (a fully interactive architecture) or are semantic and pragmatic cues used only after an encapsulated parser constructs one or more possible syntactic analyses?

If we assume that we cannot understand a sentence (or fragment) until we have selected a single syntactic analysis, a parallel parser that fails to make any commitments to a single analysis during a syntactically ambiguous region is not a viable theoretical option. Clearly, we can understand globally ambiguous sentences such as "She saw her duck" in appropriate context, we can correct grammatical errors in incomplete sentences (Marslen-Wilson, 1973), and there are numerous empirical studies yielding garden path effects (Bever, 1970; Frazier & Clifton, 1996). All of this evidence illustrates that sentence interpretation is rapid and incremental, despite considerable ambiguity. Nonetheless, this

dissertation reports a series of experiments that offer evidence suggesting that at least two alternative analyses can be maintained over a few words, under some circumstances.

In bilingual syntactic processing, structural representation is complicated because of cross-linguistic variation such as word order differences for particular structures. Frequent code-switching seems to indicate that bilinguals can process information across languages easily (Heredia & Altarriba, 2001). Studies have also shown that cross-linguistic influences can result in interference during sentence processing (e.g. Hernandez et al., 2005; Papadopoulou & Clahsen, 2003). It is thus important to understand how bilinguals store and process their two languages. One way to address the question is to look at whether prior exposure to a particular syntactic structure in one language would influence syntactic ambiguity resolution in the other language. If the two languages share syntactic representations, exposure to a particular structure in one language should increase the preference for resolving a syntactic ambiguity in favor of the structural interpretation that has just been encountered in the other language.

Before turning to the experimental studies in the dissertation, it will be beneficial to highlight the differences among various approaches to the parallelism and interactivity of the human parsing mechanism. Next, different perspectives on bilingual syntactic representations will be reviewed. Finally, the structure of the dissertation will be outlined.

1.2 Parallelism

Parsing models can be distinguished by the number of representations they construct and maintain when confronted with a syntactic ambiguity. In the context of this dissertation, I define serial parsing models as those in which a single structure is selected as each word is recognized—even if multiple analyses were considered as candidates. Corres-

pondingly, parallel parsing models as those in which two or more analyses are maintained to some degree across several words.

Most current parsing theories assume little, if any, parallelism. For instance, the garden-path model (Frazier, 1982) proposes that the parser constructs only the structurally simplest analysis. The unrestricted race model (Traxler et al., 1998; Van Gompel et al., 2001) claims that although multiple analyses are activated in a horse race, only the most probable structure would be completed based on the input constraints. On the other hand, the constraint-based competition models (e.g. McRae et al., 1998; Spivey & Tanenhaus, 1998) propose that multiple syntactic alternatives are activated in parallel and compete for selection at each word, by getting graded support from the available syntactic, lexical, and pragmatic constraints. In short, both the unrestricted race model and the constraint-based competition models are serial parsers, by our criteria, because a single structure is selected at each word position.

In a serial parsing framework, if new material appearing in a sentence can not be included into the present structure, the processor must re-structure its analysis to incorporate the new information. This reanalysis requires extra effort, which is usually accompanied by longer reading times and/or regressive eye movements in an eye-tracking paradigm (Frazier & Rayner, 1982). Theories of reanalysis have been proposed to account for the differential strength of garden-path effects. For example, Lewis (1998) distinguished between easy garden paths, for which his SNIP operator could initiate a local repair, and difficult garden paths, for which reanalysis failed because the necessary repair was out of SNIP's reach. Another approach was the Diagnosis Model (Fodor & Inoue, 1994), which maintained that reanalysis difficulty is largely dependent upon the informativeness of the

disambiguation cue: the more directly a disambiguation cue signals the appropriate repair, the lower the processing cost, with the assumption that syntactic symptoms are more effective than pragmatic symptoms. In other accounts of reanalysis, the costs are lower when some of the constituents from the initial parse can be reused for the new parse (e.g., Abney, 1989; Konieczny, 1996).

Alternatively, a parallel parser would construct and maintain multiple structures throughout the ambiguous region. A ranked parallel model (e.g. Gibson, 1991; Gorrell, 1987) allows alternative syntactic representations to be ordered according to various constraints, such as syntactic complexity, lexical frequencies, semantic information, and context. Given that the ranking of the alternative structures causes them to be differentially available to the processor, a ranked parallel model is also compatible with garden-path effects. That is to say, if disambiguation forces the parser to adopt a dispreferred structural analysis, a garden path effect arises because the structural alternatives must be re-ranked, either by changing their activation levels or by some other mechanism.

Most of the constraint-based models (e.g. MacDonald et al., 1994; Spivey & Tanenhaus, 1998) assume that although syntactic representations are initially activated in parallel, a single analysis is quickly selected, based on support from the various constraints. McRae et al.'s (1998) computational model of the constraint-based theory demonstrated how the interaction of various sources of constraints determines the activation level of the syntactic alternatives of an ambiguity. Supporting information can increase the activation of a structural alternative, and the analysis receiving the most support will be activated most. Such models are similar to parallel parsers in that the dispreferred alternative(s) receives much less activation than the selected structure. In a ranked parallel version, the

parser could maintain multiple alternatives at varying levels of activation throughout the ambiguous region of a sentence. Unlike a serial parsing framework, a parallel parser does not postulate a two-stage reanalysis mechanism because when the later-arriving information activates a dispreferred analysis, the initially preferred one will have to be inhibited.

Despite widespread adoption of serial parsing assumptions, there have been some empirical results suggesting that ranked parallelism provides a better account of garden path effects. For example, Hickok (1993) maintained that the parser computed both the preferred sentential-complement and the dispreferred RC representations in parallel when processing the ambiguous sentence *The psychologist told the wife that the man bumped that her car was stolen*. On the one hand, the parser was garden-pathed when the disambiguation required the assignment of a RC structure of the ambiguous region, suggesting that the sentential-complement reading was preferred. On the other hand, the NP *the wife* was reactivated following the presentation of the embedded verb *bumped*, suggesting that the RC reading was also computed.

Tabor and Hutchins's (2004) computational self-organizing model (SOPARSE) proposes that each new word of an ambiguous sentence activates possible attachments in parallel and that these structural alternatives compete until one of them reaches stabilization. The structural alternatives are largely determined on the basis of lexicalized syntactic knowledge. SOPARSE is a type of ranked parallel processor, because there are temporal intervals during which multiple analyses are partially active and no analysis has reached a stable state. Furthermore, SOPARSE predicts greater "digging-in" costs the longer the ranking has been established because, even without additional supporting evidence, the initially preferred attachment continues to grow in activation strength via a "rich-get-

richer" feedback mechanism designed to elevate the activation of the selected structure to a stable state over the course of several words.

How does the limited parallel account explain the well-known garden path phenomena such as the easy garden path in (1) and the difficult one in (2)? In (1), the verb's argument structure motivates postulation of two structural alternatives, a direct object complement and a sentential complement. While the former may initially be ranked higher, *the water* is consistent with both alternatives, and the sentential complement alternative should be easily recoverable for verbs like *expect* that occur frequently with sentential complements. In (2), *drink* also allows for two alternatives, a transitive and an intransitive structure. However, *the water* only supports the transitive analysis, allowing the intransitive structure to decay in activation. Central to these predictions is the assumption that alternative analyses will not linger unless they receive support from at least some of the available constraints.

1.

John expected the water to taste bad.

2.

After John drank the water tasted bad.

1.3 Interactivity

Two influential processing theories, the garden path/construal account and multi-constraint based models, differ in terms of how semantic and pragmatic cues can guide the parser.

The garden path approach maintains that an autonomous parser consults only syntactic information in the first stage of processing (Frazier & Rayner, 1982). Guided by the principle of minimal attachment, the parser must attach each new word into a single syntactic structure in the quickest possible way, namely, using the fewest syntactic nodes (see Frazier & Clifton, 1996, for a review). It is only in the second stage of processing that the parser checks the syntactic analysis against other sources of information, where initial misanalysis is revised if necessary.

Fodor and Inoue's Diagnosis Model (1994) is an example of a "syntax-first" model, in which most of the variability in reanalysis difficulty is predicted by the difficulty of determining what structural alterations are necessary to get from the current structure to the correct structure. Only a syntactic incompatibility can successfully initiate repair operations. Fodor and Inoue maintain that the reanalysis procedures are not initiated by pragmatic violations, presumably to make sure that structural revision does not take place unless it is absolutely necessary.

In contrast to the garden-path account, the multi-constraint based approach considers sentence parsing as a constraint satisfaction process, where both syntactic and non-syntactic cues are immediately utilized (MacDonald et al., 1994; Trueswell et al., 1994; Traxler et al., 1998; Van Gompel et al., 2001). A fundamental assumption in a constraint-based approach is that multiple sources of evidence are combined to determine the probability assigned to each analysis of an ambiguous sentence (MacDonald et al., 1994). Although Ferreira and Clifton (1986) did not find immediate semantic effects, Trueswell et al. (1994) did, using similar sentences in an experiment with a similar design. Crucially, they improved the manipulation of thematic constraint. They selected the initial inani-

mate nouns that were rated as atypical agents but typical themes of the following verbs, which favored a RC over a main clause continuation. As predicted, plausibility overrode the preference for minimal attachment in early syntactic ambiguity resolution: no reading slowdown was observed in the conditions with an inanimate noun.

Most constraint-based models assume that some syntactic information is associated with words and that lexical constraints can influence the early stage of syntactic analysis. Trueswell (1996) demonstrated that the frequency of the past tense and the passive participle form of an ambiguous verb has an early effect on resolving the reduced RC ambiguity. Importantly, the frequency information encoded in verbs interacted with the semantic constraint during processing: if the initial noun phrase was a good patient/theme, the correct past participle interpretation would be selected during initial processing for ambiguous verbs which had a high participle frequency (e.g. *The award accepted by the man was very impressive.*) but not for verbs with a low participle frequency (e.g. *The room searched by the police contained the missing weapon.*).

1.4 Structural Persistence

Syntactic priming in comprehension has been used to study the effects of repeating syntactic forms on the processing of temporarily ambiguous constructions (e.g. Tooley et al., 2009; Thothathiri & Snedeker, 2008, Arai et al., 2007). It has been found that the availability of a syntactic alternative of an ambiguity can be facilitated by the same structure that is previously encountered. For example, Tooley et al. (2009) showed that disambiguation towards a dispreferred reduced RC structure (e.g. *The speaker proposed by…*) was less difficult when the ultimately correct analysis has been primed than when there is

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no prime. An explanation is that syntactic priming can enhance the activation of the dis-preferred structure in memory and makes it easier to recover when necessary.

Syntactic priming in comprehension, however, is complicated by the influence of verb repetition between prime and target. One line of research (e.g. Tooley et al., 2009; Arai et al., 2007; Branigan et al., 2005) has claimed that syntactic priming in comprehension is due to overlapping information in a previously encountered structure. On this view, lexical information plays a central role in sentence comprehension, and a large amount of syntactic information is associated with lexical items (McDonald et al. 1994). Thus, word repetition facilitates subsequent lexical retrieval and thus increases the accessibility of the structural template associated with the repeated words. Tooley et al.'s (2009) event-related potential (ERP) and eye-tracking studies indicated that syntactic priming in comprehension depended on verb repetition. A reduced RC (e.g. *The child watched by the parent was playing quietly.*) elicited less processing difficulty at the disambiguating region (i.e. *by*) when following a prime sentence with a same verb (e.g. *The man watched by the woman was tall and handsome.*) but not with a synonymous verb (e.g. *The man observed by the woman was tall and handsome.*).

The lexicalist account of syntactic priming has been challenged by recent findings that priming of a syntactic structure is not linked to specific lexical items. Using a visual-world paradigm, Scheepers and Crocker (2004) found that constituent order priming in German case marking ambiguities did occur in the absence of word repetition between prime and target. For example, the first noun phrase in the sentence *Die Krankenschwester föhnt offensichtlich den Priester* (*The nurse blow-dries apparently the priest*) can serve as either the subject (agent) or the object (patient) of the sentence, which carries the

nominative and the accusative case, respectively. The results revealed that the ambiguous noun phrase was more likely to be interpreted as a subject after a SVO prime (e.g. *Der Regisseur lobte insbesondere den Produzenten* (*The director [nom] commended in particular the producer [acc]*)) and as an object after an OVS prime (e.g. *Den Regisseur lobte insbesondere der Produzent* (*The director [acc] commended in particular the producer [nom]*)) compared to a neutral baseline. Since the prime sentence contained both the nominative case *der* and the accusative case *den*, the comprehension priming must involve constituent order representations. The results showed that prior exposure to a particular order guided the resolution of a temporary constituent order ambiguity associated with a case-ambiguous noun phrase in sentence-initial position. Crucially, the observed comprehension priming was not tied to the repetition of the ambiguous noun phrase across sentences.

It is important to note that lexically-independent syntactic priming in comprehension is not incompatible with the constraint-based lexicalist theory (MacDonald et al., 1994; Trueswell & Tanenhaus, 1994). The theory assumes a constraint-satisfaction approach to syntactic ambiguity resolution, such that all relevant constraints are integrated immediately on a word-by-word basis to influence syntactic processing. Crucially, the processor is highly constrained by structural preferences of individual lexical items, such as the frequency of a verb's alternative argument structures and the likelihood of a verb form being used as a past tense main verb or as a past participle. Nevertheless, syntactic processing is not only guided by lexical-level information. The lexical constraints are weighed against other constraints at the structural and the discourse level during syntactic ambiguity resolution (Spivey & Tanenhaus, 1998).

Syntactic priming can function as a constraint at the structural level that can be dissociated from individual lexical items. That is, prior exposure to a particular structure increases the parser's preference of generating the same syntactic frame. This experience-based structural constraint can be incorporated in the constraint-based theory, which maintains that syntactic analysis is constrained by lexical co-occurrence frequency computed based on the parser's prior experience with language. It seems natural to assume that an exposure-based processing system must be sensitive to non-lexical representations in order to make use of statistical regularities beyond the lexical level. In this vein, syntactic priming can affect parsing decisions, given that the parser can be tuned by prior experience with a particular syntactic configuration unbound to the lexicon.

1.5   Cross-linguistic Interaction

A long-standing debate in the psycholinguistic literature on bilingualism centers on the separation or integration of bilinguals' two languages. Structural priming has been commonly used to investigate whether the two languages of a bilingual speaker can be simultaneously active (e.g. Loebell & Bock, 2003; Hartsuiker et al., 2004; Schoonbaert et al., 2007; Bock et al., 2007). In this paradigm, participants are shown the same or similar structures from two languages. An integrated syntactic system would allow for one language to influence the other during sentence processing. In a separate bilingual system, however, the two languages would operate independently without influencing each other. In this case, cross-language priming would not occur or would necessarily result from strategic processing.

Studies (e.g. Loebell & Bock, 2003; Hartsuiker et al., 2004) have shown that structural priming occurs across languages, making a structure from one language more likely to

occur after its corresponding structure is used in another language. Structural priming has provided insight into bilingual syntactic representation at the abstract level, as the priming effects have been observed in the absence of lexical repetition and semantic relatedness between prime and target sentences (Bock & Griffin, 2000; Bock, 1989), although priming can indeed be enhanced by verb repetition (e.g. Branigan et al., 2000). The cross-language priming effects suggested that the two linguistic systems are interdependent during bilingual processing, at least to a certain degree.

One of the controversial issues, however, is to what degree the syntactic representations of the two languages are integrated. In particular, does cross-language priming rely on word order repetition? That is, can prior exposure to a syntactic structure in one language facilitate the processing of the corresponding structure if it has a different word order in the other language? Many models of sentence representation (e.g. Bock & Levelt, 1994; Garrett, 1975) distinguish between a functional and a positional level of processing. The functional level represents syntactic functions (e.g. verb, subject, object, and modifier) of lexical items as well as syntactic dominance relations between constituents. The positional level specifies the order of constituents based on the representation computed at the functional level. For example, the representation of a RC structure (e.g. *The general who trained soldiers was tired.*) can consist of two levels. At the functional level, the noun phrase *the general* receives the subject function and the second noun phrase *the soldiers* the object function. The RC serves as a modifier of the extracted head noun phrase. At the positional level, the linear relations between constituents are computed. English RC structure is head-initial; so the head noun phrase precedes the RC in the positional representation. The serial order between the head noun phrase and the RC is reversed in a

language like Chinese, where the RC structure is head final. Under the two-level account, the same kind of functional relations can be expressed with a number of word orders, even in languages with a relatively flexible word order.

Hartsuiker and Westenberg (2000) observed syntactic priming of word order in Dutch, which allows word order variation of auxiliary and past participle in subordinate clauses. The same word orders (i.e. participle-final or auxiliary-final) tended to be used in prime and target sentences (e.g. *John told the detective that he nothing had seen/seen had*), even though the structural alternatives do not differ in concept. Hartsuiker and Westenberg argued that the effect of word order priming provided evidence for the positional level of processing, where word order is specified independent of grammatical function. However, Pickering et al. (2002) found that shifted constructions (e.g. *The racing driver showed to the helpful mechanic the problem with the car.*) did not prime the production of prepositional datives (e.g. *The patient showed his leg to the doctor.*), which differ only in the serial order of direct and indirect objects. Pickering et al. claimed that word order repetition was necessary for syntactic priming to occur because serial order of constituents was not computed separately from other grammatical relations.

1.6 Overview

The dissertation comprises a series of experiments investigating whether the parser can maintain multiple structural alternatives of an ambiguity and how semantic plausibility influences the early stage of syntactic processing. Moreover, I explore the conditions under which priming occurs in bilinguals.

In Chapter 2, I introduce the Chinese syntactic ambiguity, *Verb NP$_1$ de NP$_2$*, that is examined in the dissertation. In Chapter 3, I first review theoretical positions and empiri-

cal evidence for and against parallel processing. Then, I present two reading time studies, testing the predictions made by serial and parallel models regarding easy and hard structural reanalyses. Chapter 4 and 5 extend the investigation to the representation of syntax. Chapter 4 examines syntactic priming during the comprehension of the Chinese ambiguity; Chapter 5 focuses on cross-linguistic priming between Chinese and English, which differ in the word order of the RC structure. Chapter 6 concludes the dissertation by summarizing the findings of the four experimental studies and discussing directions for future work.

Chapter 2

Syntactic Ambiguity Resolution in Chinese

2.1 The Verb NP$_1$ de NP$_2$ Construction

Using a self-paced word-by-word reading paradigm, Zhang et al. (2000) investigated the *Verb NP$_1$ de NP$_2$* construction, which is temporarily ambiguous between a complement clause (CC) structure (Figure 1a) and a relative clause (RC) structure (Figure 1b). For example, the first four words in (3) could mean either *to train the soldiers' general* (CC) with *de* being a genitive marker, or *the general who trains soldiers* (RC) with *de* serving as a RC marker in a head-final construction.

(1a) complement clause (CC)   (1b) relative clause (RC)
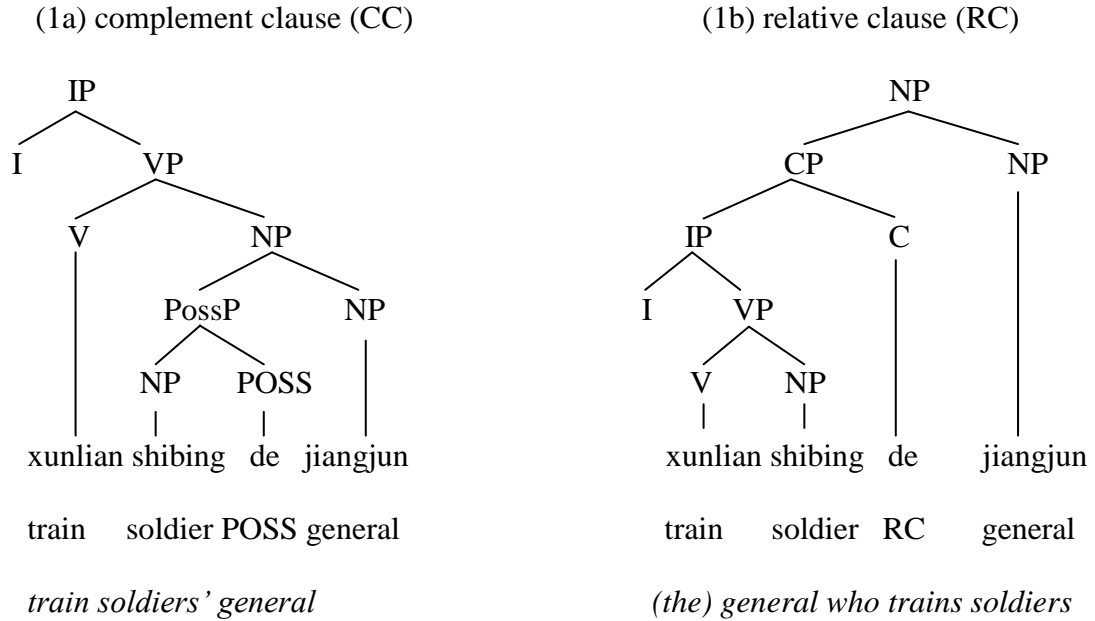
Figure 1. Two structural analyses of the ambiguous *Verb NP₁ de NP₂* construction.

3.

xun4lian4 shi4bing1 de jiang1jun1…

train soldier POSS/RC general…

train soldiers' general/(the) general who trains soldiers…

It was found that a semantic constraint led to a parsing commitment to a particular structure during the ambiguous region. A plausibility cue was provided at NP_2 in sentences like (4), to bias the ambiguous phrases towards a reading of RC or CC, or remain neutral. Zhang et al. (2000) found garden-path effects one word after the disambiguation when RC-biased items were disambiguated as CC (4a) and vice versa (4b). More importantly, garden path effects appeared in the semantically balanced phrases when they were disambiguated as CC (4c), which suggests that the RC is the default analysis. There are

several reasons why the RC might be preferred. First, the RC is structurally simpler by the principle of minimal attachment, and allows immediate thematic role assignment for NP_1, as the direct object of the verb. Second, the RC has an explicit subject (in the final position) and thus provides a complete propositional meaning, whereas the CC does not have an external argument. Third, Zhang et al. found that the syntactically contingent frequency of *de* as a RC marker (as in the RC) in this construction is considerably higher than *de* as a possessive marker (as in the CC). In the context of *Verb NP₁ de NP₂*, 70 percent of the 1000 syntactically ambiguous items that were randomly selected from a corpus[1] were RC.

4.

(a) RC-biased disambiguated as CC

[dai4man4 ke4ren2 de hai2zi] zhi1hou4, zhou1li4 xin1li3 you3xie1 ao4hui3

[slight guest POSS child] after, Zhou Li in the mind somewhat regretful

After [slighting the guest's child], Zhou Li felt somewhat regretful.

(b) CC-biased disambiguated as RC

[zhi3ze2 bao4she4 de ji4zhe3] ren4wei2 xin1wen2 bao4dao3 bi4xu1 ke4guan1

[censure newspaper-office RC reporter] think news report must objective

[The reporter that censured the newspaper office] thought that news reports must be objective.

(c) balanced disambiguated as CC

[zhuang4dao3 xiao1ming2 de che1zi] zhi1hou4, liang3ge4 hai2zi fei1chang2 hai4pa4

[run into Xiao Ming POSS bicycle] after, two children very scared

After [running into Xiao Ming's bicycle], the two children were very scared.

Focusing on the construction of *Verb NP$_1$ de NP$_2$*, Hsieh et al. (2009) aimed to provide evidence that distinguishes parallel from serial parsing models. The ambiguity is well-suited to the difficult empirical problem of distinguishing serial and parallel syntactic processing, because a revision from RC (Figure 1b) to CC (Figure 1a) requires a complete reanalysis of the first part of the sentence.

Crucially, the RC was the preferred analysis, based on structural simplicity, semantic completeness, corpus statistics, and sentence completion data. Hsieh et al. (2009) conducted a sentence completion survey with the critical stimuli in order to justify the claim that a RC is the default structure. The results showed that all the participants began their completion with a noun phrase for all the critical items. This noun phrase was part of a RC completion ninety-five percent of the time (911/960) while the other five percent of responses were CC completions. All items had at least fifty percent RC completions, and only three items had fewer than eighty percent RC completions. Thus, the RC analysis is strongly preferred over the CC analysis for the stimuli.

Consider the examples in (5) and (6): (5a) and (6a) contained the ambiguous construction in the first four words; (5b) and (6b) were unambiguous controls[2] for (5a) and (6a), respectively, where NP$_1$ was replaced with an adjective, forcing *de* to be an attribu-

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[2] It is not entirely impossible for the first four words in (5b) and (6b) to have a relative clause continuation, such as *[fen3shua1 lao3jiu4 de fang2jian1 de gong1ren2…] [paint old ATT room RC worker] 'The worker that painted the old rooms…'*. However, such a sentence with two nearly adjacent *de*s should be rare. In fact, the first *de* is usually dropped in an expression like this to avoid redundancy, as the *de* following an adjective is omissible and in fact omitted about 90 percent of the time based on our corpus analysis.

tive marker. Thus, both (5b) and (6b) contained unambiguous attributive structures. They served as control structures for (5a) and (6a) because they were matched for lexical content, but did not contain the syntactically ambiguous sequence. Because the ambiguous conditions were always disambiguated as the less preferred CC structure, a processing cost for the ambiguous conditions compared to the unambiguous conditions is likely to reflect costs associated with reanalysis under a serial account or re-ranking under a parallel account.

Both syntax-first and multi-constraint theories predict that NP_1 would be taken as the direct object of the initial verb in both (5a) and (6a). Then, at the homograph *de*, a serial parser would continue to construct an RC, whereas a parallel parser would compute both an RC and a CC with the former ranked higher. Examples (5a) and (6a) differed with regard to our animacy manipulation at NP_2, which served to either (semantically) disambiguate the ambiguous construction as the CC (5a) or support the RC (6a). Finally, the structure for both the ambiguous phrases in (5a) and (6a) was disambiguated as a CC at the conjunction (*before/after/while*).

Most importantly, the two ambiguous conditions differed with respect to the word position at which revision from RC to CC was required: either NP_2 (word 4 in (5a) below) or the conjunction (word 5 in (6a) below). There have been no reanalysis mechanisms proposed that could accomplish such restructuring without considerable processing costs, regardless of the word position at which revision is necessary. As noted above, reanalysis of the RC structure as the CC structure requires a complete overhaul rather than a selective revision. Therefore, it is not the type of reanalysis that proposed revision mechanisms could accomplish cheaply or quickly, if at all (Abney, 1989; Fodor & Inoue, 1994;

Frazier & Clifton, 1998; Frazier & Rayner, 1982; Konieczny, 1996; Lewis, 1998; Pritchett, 1991; Stevenson, 1998; Sturt et al., 1999). Even allowing for new proposals about how reanalysis proceeds, it is difficult to image one that could easily transform the structure in Figure (1b) into the structure in Figure (1a).

The Inanimate Ambiguous condition (5a) was semantically disambiguated as a CC because NP$_2$, *room*, must be the direct object of the verb phrase *paint* rather than the head noun that performs the action of painting an apartment. In the Animate Ambiguous condition (6a), although both the interpretations of RC (*the general that trained the soldiers*...) and CC (*training the soldiers' general*) were possible, the initially-adopted RC is most plausible. That is, it is more plausible that a general trained soldiers than that the general was trained. So *general* is likely to be assigned the thematic role of Agent. Thus, in the Animate Ambiguous condition the RC analysis was expected to become deeply entrenched as semantic evidence increased through NP$_2$.

5. *Inanimate*

(a) [fen3shua1 gong1yu4 de fang2jian1] zhi1hou4, xiao3wang2 hai2 da3sao3 le ke4ting1

  [paint apartment POSS room] after, Wang also clean PERF living room

  After [painting the apartment's rooms], Wang also cleaned the living room.

(b) [fen3shua1 lao3jiu4 de fang2jian1] zhi1hou4, xiao3wang2 hai2 da3sao3 ke4ting1

  [paint old ATT room] after, Wang also clean PERF living room

  After [painting the old rooms], Wang also cleaned the living room.

6. *Animate*

(a) [xun4lian4 shi4bing1 de jiang1jun1] zhi1hou4, zong3si1ling4 fa1biao3 le jian3duan3

yan3shuo1

[train soldier POSS general] after, commander give PERF short speech

After [training the soldiers' general], the commander gave a short speech.

(b) [xun4lian4 nian2qing1 de jiang1jun1] zhi1hou4, zong3si1ling4 fa1biao3 le

jian3duan3 yan3shuo1

[train young ATT general] after, commander give PERF short speech

After [training the young general], the commander gave a short speech.

Substantial processing costs, reflected in increased reading times and regressive eye movements, were observed when the CC structure was required by the syntactic disambiguation at word 5 (i.e. the conjunction *before/after/while*), in the Animate Ambiguous condition. However, there was no measurable difficulty at word 4 in the Inanimate Ambiguous condition, where the inanimate NP_2 presented a semantic disambiguation towards the CC, suggesting that the more complex CC analysis was already available. In sum, the minimal costs for the Inanimate Ambiguous condition in the eye-tracking paradigm are in sharp contrast with the strong garden path effects observed in the Animate Ambiguous condition.

Disambiguation to the dispreferred CC analysis became more difficult the longer the RC analysis continued to receive support. The contrast in processing difficulty between the Inanimate and Animate Ambiguous conditions poses a challenge for any parsing model that assumes that only one analysis remains available after a syntactic choice point. Hsieh et al. argued that both the RC and the CC analyses were maintained during the ambiguous region. The reactivation of the lowly ranked CC was costly at word 5 in the

Animate Ambiguous condition as the syntactically preferred RC continued to gain activation from the semantic evidence and thus became deeply entrenched through NP$_2$, *general*, i.e. it is more plausible that a general trains soldiers than that a general is to be trained. On the other hand, the reactivation of the dispreferred CC involved no processing costs at word 4 in the Inanimate Ambiguous condition because the incorrect RC had only gained strength from the syntactic constraint over a relatively short time. In short, as the preferred RC became elevated over time, the lower-ranked CC decayed, which increased the costs of reactivation when necessary.

In fact, a limited parallel version of a multi-constraint based theory, such as Tabor and Hutchins' (2004) computational SOPARSE model, provides the best account of the findings in Hsieh et al. (2009). When reading the *Verb NP$_1$ de NP$_2$*, the parsing system initially attached NP$_1$ as the direct object of the sentence initial verb. However, the lexical ambiguity of *de* introduced two structural possibilities: *de* could be attached to the existing structure as a RC marker or it could head a possessive modifier, with NP$_1$ as the possessor. At *de*, the RC analysis should be ranked highest. However, at the next word NP$_2$, animacy supporting the CC analysis becomes available in the Inanimate Ambiguous condition, raising the activation level of the CC analysis, so that syntactic disambiguation at the next word is consistent with a highly activated analysis. In the Animate condition, however, the CC remains in low activation at NP$_2$, while the animacy constraint further elevates the activation level of the RC. The findings are a good demonstration of the SOPARSE model's "digging-in" effects: the longer the parser is committed to a misanalysis (i.e. the RC is supported one word longer in the Animate than in the Inanimate condition)

the more severe a garden path is, as the misanalysis continue to gain activation strength via the "rich-get-richer" mechanism.

While there have been a variety of reanalysis mechanisms proposed, there is general agreement concerning which garden paths should be difficult. Difficult garden paths are characterized by major structural changes, at least some of which are non-local. Fodor and Inoue's serial Diagnosis Model (1994) fails to predict a difference in reanalysis difficulty between the Inanimate and Animate conditions because only a syntactic incompatibility can successfully initiate repair operations. Thus, for the stimuli, repairs would be initiated at word 5 in both the Animate and Inanimate ambiguous conditions, and no difference in reanalysis difficulty would be predicted, because the same structural symptom would cue reanalysis in both cases. Regardless of whether the adverb at word 5 is considered an informative or an uninformative diagnostic cue, Fodor and Inoue predict equivalent garden path effects in the Animate and Inanimate conditions. Lewis' SNIP account (1998) predicts successful reanalysis when a single, local structural dependency must be broken. The SNIP operator is able to fix a misanalysis easily if the repair falls under the maximal projection containing the incompatibility. Lewis maintained that a single SNIP repair adds about 50-100 ms of processing time. Changing from a RC structure to a CC structure at word 4 or 5 in the stimuli would require multiple instances of detaching and relinking constituents, so it presumably would take considerably longer under Lewis' metric—if SNIP could reach into the CP and IP embedded within the complex NP (see Figure 1b) to detach NP_1 and *de* from the tree. But in fact, such operations are not local enough for SNIP, and as a result, reanalysis should fail for both the Animate and Inanimate conditions.

The reanalysis accounts that have been considered predict that difficult garden path effects should result from reanalysis of a RC as a CC in both critical conditions. None of the proposed reanalysis mechanisms are consistent with the finding that reanalysis costs were considerably less in the Inanimate condition compared with the Animate condition. Hsieh et al. (2009) concluded that the finding was most consistent with a limited parallel account. The absence of a garden path effect at the disambiguation of the Inanimate sentences suggested that the parser already had the correct CC analysis at the previous region. Given that a relevant semantic cue was available only at the fourth word, the parser probably re-ranked the structural alternatives, demoting the simpler RC and promoting the more complex CC at this point, with minimal processing costs. There was no evidence of the re-ranking in the dependent measures, but re-ranking at NP_2 could be very low cost if the lower ranked representation had been constructed and maintained up to this point.

2.2 Eye Movements in Chinese

Hsieh et al. (2009) utilized the eye-tracking paradigm, which allows natural reading, to investigate differential processing difficulty during the time course of sentence comprehension. Experiments 1 and 2 in the dissertation employed the same experimental paradigm to address the question of how the interaction between syntactic and semantic information during the ambiguous region affects processing difficulty at the disambiguation region. The combination of long fixations and regressive eye movements at the disambiguation point are generally taken as evidence of garden path in eye movement studies of reading. The linking assumption is that the cognitive processes of anomaly detection and structural revision are reflected in the eye movement data, as linguistic processing occurs as soon as the relevant word is fixated. For example, first fixations and first-pass

regressions are generally informative of garden path effects during the earliest stages of sentence processing.

Research on the eye movements during reading has shown that average fixation durations are similar (about 225-250 msec) for Chinese and English readers (Chen et al., 2003; Rayner, 1998). Nevertheless, Chinese and English eye movement patterns differ in other aspects due to orthographic differences. Because the orthography of Chinese is much more lexically dense than the orthography of English, the perceptual span is correspondingly smaller, but the number of words encompassed with the perceptual span is not very different across the two languages. The perceptual span of Chinese readers extends from 1 character left of fixation to 3 characters to the right (i.e., approximately two to three words) when they are reading from left to right (Inhoff & Liu, 1998), while English readers have a span extending from 3-4 letters left of fixation to about 14-15 letters to the right (i.e., about three words) (Rayner, 1998). A second orthographic factor is that Chinese characters are presented in a continuous string, without spaces between words—unlike English. Because Chinese words can be one or more characters long, the word boundaries are often ambiguous, and the lack of spaces between words could conceivably increase parafoveal processing of upcoming words when reading Chinese, compared to English. Unfortunately, little is known about possible differences between Chinese and English with respect to the parafoveal processing of upcoming words, nor is it clear how much phonological and semantic processing occurs for characters in the periphery during Chinese reading (see Feng, 2006, for an overview). Third, Chinese readers exhibit a slightly higher regression rate (about 15%) than English readers (about 10%) (Chen et al., 2003; Rayner, 1998). Finally, average saccade length is shorter in Chinese (about 2-2.5

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characters) than in English (about 7-9 letters or 1.5 words), due to the higher information density of the Chinese text (Chen et al., 2003).

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Chapter 3

Semantic Support Predicts Processing Difficulty in Chinese

3.1 Introduction

Revising a misanalysis of a syntactic ambiguity elicits greater processing difficulty in some cases than in others. For example, Ferreira and Henderson (1991) showed that the sentence "*While the boy scratched the dog sleeping peacefully yawned.*" elicited greater reanalysis difficulty than "*While the boy scratched the dog yawned.*" What factors contribute to processing difficulty at disambiguation when the dispreferred structure is required? Both serial and parallel syntactic processing theories have been proposed, which differ in how the parser responds to syntactic ambiguity. I define a serial parser as one that is committed to a single structure at each word position in an ambiguous sentence, even if multiple structural alternatives are considered initially. On the other hand, a parallel parser maintains multiple alternative structures of an ambiguity across several words.

Each theory has its own metaphor to describe how alternatives are compared. For example, a serial model might postulate either a race to construct the various alternatives or a competition for activation, as the mechanism for committing to a structure at an ambiguity. In this chapter, I will use an activation metaphor because it works well for both serial and parallel models.

A serial parser has to reparse or repair the initial parse when the existing structure proves to be incompatible with the input string. The more recent repair accounts (e.g. Fodor & Inoue, 1994; Lewis, 1998) are cue-driven and suggest that repairing an incorrect parse is easy if the syntactic disambiguation effectively signals the local parsing error. In contrast, under a limited, ranked parallel account, such as that proposed by Gibson (1991), multiple structural analyses are ranked based on the preferences of the available constraints, and re-ranking occurs when the highly ranked structure is inconsistent with the disambiguating material. Gibson (1991) maintains that the strength of all possible analyses are computed and compared at each word position, with the one that receives most support ranked highest. It is worth noting that only a limited number of structures are retained during the ambiguous region due to memory constraints.

Unlike the serial models in which processing difficulty is determined by the efficacy of the disambiguating cue and the scope of structural repair, a limited, ranked parallel parser attributes processing difficulty to structural re-ranking. The critical factor that affects misanalysis difficulty is the relative activation strength of the candidate analyses. Like other constraint-satisfaction models, a limited, ranked parallel version would allow all sources of information to have an immediate and direct effect on the activation strength of the candidate analyses at a syntactic ambiguity. Crucially, the cost of promoting a dispreferred structure should escalate if the initially preferred analysis receives more support during the ambiguous region while the dispreferred alternative becomes less accessible due to lack of support.

Computational modeling has illustrated how such reranking costs could emerge within various theoretical approaches. For example, Green and Mitchell's (2006) simulation

of a constraint-based competition theory (McRae et al., 1998) showed that misanalysis difficulty increased when the initially preferred structure had previously received much higher activation relative to the ultimately required analysis, than when the two candidates were activated to approximately the same extent. Likewise, the surprisal theory proposed by Hale (2001) suggests that processing difficulty should occur when later-arriving material requires a dispreferred structure that has not been allocated sufficient resources during the previous region. The surprisal costs of an unexpected attachment should be higher than those of a predictable alternative that is well supported by the available constraints.

Tabor and Hutchins's (2004) SOPARSE model is also a parallel parsing system in the sense that multiple attachments are established as each word is received and that these alternatives will be carried along over the course of several words until one reaches the threshold. In particular, the model predicts that "digging in" contributes to misanalysis difficulty: the longer the parsing preference has been established, the harder it is to recover from the garden path. The initially preferred analysis will continue to grow in activation strength and finally reach stability via a "rich-get-richer" feedback mechanism if it receives support from the available constraints. Meanwhile, the dispreferred representation will decay over time, and the reactivation would become costly.

In short, although the serial repair models and the limited, ranked parallel models both predict processing costs when the current parsing preference conflicts with the continuation of the sentence, the two approaches make distinguishable predictions with respect to when processing difficulty will arise. Under a serial account, structural repair should be least costly when it is local, when the correct structure is obvious, and when the

new structure can retain some of the dominance relationships between words from the old structure. On the other hand, a ranked parallel parser is sensitive to the activation difference between the alternative structures prior to disambiguation. Structural revision should be costly if an analysis of low availability has to be reactivated after the preferred interpretation has become deeply entrenched through the contribution of time and/or the supporting evidence from the relevant constraints even if the length of the ambiguous region is held constant.

Hsieh et al. (2009) investigated the construction of *Verb NP$_1$ de NP$_2$*, which is ambiguous between a relative clause (RC) structure and a complement clause (CC) structure, as shown in Figure (1) above. The ambiguity hinges upon the lexical ambiguity of the homograph *de*. For example, the first four words of (7a) could mean either *the general who trains soldiers* (RC) with *de* serving as a RC marker, or *to train the soldiers' general* (CC) with *de* being a genitive marker. Crucially, the RC was the preferred analysis, based on structural simplicity, semantic completeness, corpus statistics, and sentence completion data.

Disambiguation to the dispreferred CC analysis became more difficult as the RC analysis received support one word longer. Substantial processing costs were observed at word 5 in (7a), where the syntactic disambiguation (i.e. the conjunction *before/after/while*) forced the CC analysis. However, there was no measurable difficulty at word 4 in (8a), where the inanimate *NP$_2$* provided a semantic disambiguation towards the CC. Processing difficulty of the ambiguous sentences, (7a) and (8a), was evaluated with respect to the unambiguous control sentences, (7b) and (8b), respectively, where *NP$_1$* was replaced by an adjective, forcing *de* to be an attributive marker.

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7. *Animate*

(a) [xunlian shibing de jiangjun] zhihou, zongsiling fabiao le jianduan yanshuo

    [train soldier POSS general] after, commander give PERF short speech

    After [training the soldiers' general], the commander gave a short speech.

(b) [xunlian nianqing de jiangjun] zhihou, zongsiling fabiao le jianduan yanshuo

    [train young ATT general] after, commander give PERF short speech

    After [training the young general], the commander gave a short speech.

8. *Inanimate*

(a) [fenshua gongyu de fangjian] zhhou, xiaowang hai dasao le keting

    [paint apartment POSS room] after, Wang also clean PERF living room

    After [painting the apartment's rooms], Wang also cleaned the living room.

(b) [fenshua laojiu de fangjian] zhhou, xiaowang hai dasao le keting

    [paint old ATT room] after, Wang also clean PERF living room

    After [painting the old rooms], Wang also cleaned the living room.

The authors argued that both the RC and the CC analyses were maintained during the ambiguous region of (7a) and (8a). The reactivation of the lowly ranked CC was costly at word 5 in (7a) as the syntactically preferred RC continued to gain activation from the semantic evidence and thus became deeply entrenched through NP_2, *general*, i.e. it is more plausible that a general trains soldiers than that a general is to be trained. On the other hand, the reactivation of the dispreferred CC involved no processing costs at word 4 in

(8a) because the incorrect RC had only gained strength from the syntactic constraint and only over a relatively short time.

3.2   Experiment 1

Hsieh et al. (2009) confounded the length of the ambiguous region with semantic support for the two alternatives: the condition with the longer ambiguous region also had more semantic support for the initially preferred analysis. The current study investigated whether the difficulty of structural revision varies as a function of the relative support for the alternative interpretations. Using the Chinese ambiguous construction *Verb NP$_1$ de NP$_2$* (adopted from Hsieh et al., 2009), two eye-tracking experiments manipulated the strength of support for the two analyses alone, with the length of the ambiguous region held constant. The revision difficulty should escalate if the preferred RC analysis is given additional support during the ambiguous region.

An example of the experimental materials is provided in (9) and (10) below. The ambiguous sentences (9a) and (10a) contained the construction *Verb NP$_1$ de NP$_2$* in the first four words, which is temporarily ambiguous between a CC structure and a RC structure. The sentences were disambiguated as the dispreferred CC analysis at word 5, the conjunction (*before/after/while*). Each of the ambiguous conditions was compared to an unambiguous control, such as (9b) and (10b), in where *NP$_1$* was replaced by an adjective.

9.

(a) *Strong RC-bias Ambiguous*

[xunlian shibing de jiangjun] zhihou, zongsiling fabiao le jianduan yanshuo

[train soldier POSS general] after, commander give PERF short speech

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After [training the soldiers' general], the commander gave a short speech.

(b) *Strong Unambiguous*

[xunlian nianqing de jiangjun] zhihou, zongsiling fabiao le jianduan yanshuo

[train young ATT general] after, commander give PERF short speech

After [training the young general], the commander gave a short speech.

10.

(a) *Weak RC-bias Ambiguous*

[anwei bingren de jiashu] zhihou, nage hushi likai le bingfang

[comfort patient POSS relative] after, that nurse leave PERF ward

After [comforting the patient's relative], the nurse left the ward.

(b) *Weak Unambiguous*

[anwei beishang de jiashu] zhihou, nage hushi likai le bingfang

[comfort sad ATT relative] after, that nurse leave PERF ward

After [comforting the sad relative], the nurse left the ward.

The experiment manipulated the supporting evidence for the RC and the CC struc-tures, such that the semantic constraint provided stronger support for the RC reading in (9a) than in (10a), although the RC structure was syntactically preferred in both cases[3]. In (9a), the Strong RC-bias Ambiguous condition, the semantic evidence strongly favored the RC interpretation: it is much more plausible that a general trains soldiers (RC) than a

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[3] Hsieh et al.'s (2009) sentence completion data showed that the sentence fragment *Verb NP₁ de* was continued with a noun phrase, which was part of a RC completion 95 percent of the time (911/960). Only 5 percent of the responses were CC completions. The results were consistent with Zhang et al.'s (2000) cor-pus data that revealed that the syntactically contingent frequency of *de* as a RC marker (as in the RC) in the context of *Verb NP₁ de NP₂* is considerably higher (70 percent out of 1000 randomly selected items) than *de* as a possessive marker (as in the CC).

soldier's general is to be trained (CC). In (10a), the Weak RC-bias Ambiguous condition, the two readings were semantically and pragmatically more balanced: it is almost equally plausible that a family member comforts a patient (RC) and that a patient's family member is to be comforted (CC).

If the relative activation level of multiple parses is determined by the strength of support from the relevant constraints rather than merely by the duration of the commitment to the incorrect parse, the Strong RC-bias Ambiguous sentences should evoke much stronger activation of the RC, which received support from both the syntactic and the semantic constraints, than the CC reading. However, the Weak RC-bias Ambiguous sentences should produce similar activations between the syntactically preferred RC and the plausible CC analyses. Therefore, the hypothesis was that the difficulty of recovery from the misanalysis should rise as the initially preferred RC structure gained more strength relative to the CC structure.

3.2.1 Predictions

Limited, ranked parallel models and serial models make different predictions regarding the cost of structural revision from the preferred RC to the CC analysis. Processing difficulty was evaluated with respect to unambiguous control conditions, with the critical predictions localized to word 5, the disambiguating conjunction.

Reranking models assume that processing cost is determined by the availability of the dispreferred structure when required at disambiguation. In other words, structural revisions are easy in cases where an incorrect representation has not become too entrenched. In this view, processing difficulty should be greater at word 5 in the Strong RC-bias Am-

biguous condition, (9a), than in the Weak RC-bias Ambiguous condition, (10a). The dispreferred, yet correct CC, should be more easily reranked in the latter case.

On the other hand, serial models predict that reanalysis in (9a) and (10a) should induce the same degree of difficulty, because the RC analysis is always constructed for the first four words and the analysis must always be revised to CC at word 5. A repair mechanism, such as *snip* (Lewis, 1998) or the diagnosis parser (Fodor & Inoue, 1994), relies on structural cues to detect the error in the existing parse at word 5. A repair would not be costly if the modification were local (i.e. "within the maximal projection containing the inconsistency" Lewis, 1998), but the revision of the RC as the CC structure is not local. The modification extends beyond the maximal projection of the *NP* in the previously built RC parse, as shown in Figure (1) above.

3.2.2 Plausibility Norming Survey

A plausibility norming survey (included in Appendix A) was conducted in order to measure the plausibility difference between the Strong RC-bias Ambiguous structures and the Weak RC-bias Ambiguous sentences. Twenty-four native Mandarin Chinese speakers from Taiwan who did not participate in the experiments completed the study. The critical items used in the experiment were presented up to the fourth word, namely *Verb NP$_1$ de NP$_2$*. Participants were asked to judge the interpretations of the ambiguous items on a 7-point scale based on the plausibility of the two alternative readings, that is, how likely the described events were to occur in the real world. One endpoint of the scale (coded as 7) indicated that the phrase was highly likely to have the RC interpretation. The other endpoint (coded as 1) represented that the CC interpretation was much more plausible. The middle number (coded as 4) indicated that the phrase was balanced between the

two readings. The forty stimulus items were interspersed with forty fillers of the same structure but with various degrees of CC bias. Two experimental lists with different item orders were created.

The mean plausibility rating for the Strong RC-bias Ambiguous items was 6.23 and that for the Weak RC-bias Ambiguous items was 4.11. The plausibility rating for each item is presented along with the items in Appendix A.

3.2.3 Method

<u>Participants</u>

Thirty-two native speakers of Mandarin Chinese from Taiwan were recruited from the University of Michigan community. All had normal or corrected-to-normal vision and were paid a nominal sum for their participation.

<u>Materials</u>

A total of 40 sets of critical items were typed in traditional Chinese characters with 20 sets in each of the Strong RC-bias Ambiguous (adapted from Hsieh et al., 2009) and the Weak RC-bias Ambiguous versions. All the sentences were 10 words long plus a period at the end, and were displayed in one line on the computer screen. As shown in (9) and (10) above, structural ambiguity was a within-item factor, whereas plausibility was a be-tween-item factor. The experiment thus included four types of critical sentences: Strong-bias Ambiguous (9a), Weak-bias Ambiguous (10a), and two Unambiguous controls (9b) and (10b).

Each pair of critical sentences comprised an ambiguous condition and an unambi-guous control condition, which differed only at the second word. In the ambiguous condi-tion, the second word was a NP (which was referred to as NP_1), in the unambiguous con-

dition, the second word was an adjective. In the ambiguous conditions, NP_1 was a potential object of the initial verb; NP_2 was an animate noun, which could be either the object of the initial verb or the head noun modified by the preceding RC. Crucially, in Strong-bias condition (9a) NP_2 was more likely to be a head noun (as in the RC) rather than the object of the initial verb (as in the CC), whereas in the Weak-bias condition (10a), it was equally plausible for NP_2 to be a head noun or an object.

Plausibility and ambiguity were counterbalanced across two presentation lists. Each list contained ten ambiguous and ten unambiguous sentences from each of the Strong-bias and Weak-bias sets. Two versions of an item were never presented to the same participant. The 40 critical items were pseudo-randomly embedded within 60 filler sentences of various types in order to prevent participants from being aware of the experimental design. 20 of the fillers were from another study using different ambiguous structures, some of which consisted of semantic violations. Altogether, 33 of the 100 sentences became anomalous at some point in the sentence.

Procedure

Participants read sentences on the computer screen while their eye movements and fixations were recorded with an EyeLink II eye-tracker. The calibration and validation procedure was completed prior to the experiment. At the beginning of every trial, a dot appeared on the center of the screen, which was then replaced with the sentence once the fixation was stable. The participants began with six practice trials to become familiar with the procedure. They were instructed to read at the normal rate and to press a button to proceed to the next trial. One-third of the trials were followed by a comprehension

question, to which the participants had to respond by pressing a yes/no button. For fifty percent of the questions the correct answer was "yes."

3.2.4 Results

Five dependent measures are reported for the first five words of the critical trials (i.e. *Verb NP₁ de NP₂ Conjunction*): first-fixation durations (Figure 2), gaze durations (Figure 3), regression-path durations (Figure 4), probability of first-pass regressions (Figure 5), and total times (Figure 6). Analysis was localized to word 5, the disambiguating conjunction. Earlier regions are also graphed in order to catch any unpredicted differences among conditions prior to the critical region.

A 2 (list) x 2 (structural ambiguity) x 2 (semantic bias) repeated measure ANOVA was carried out, both by participants and by items, on the condition means for each dependent measure. Table 1 summarizes the analyses. At the conjunction, ANOVAs yielded main effects of ambiguity and bias, as well as an interaction between the two factors, for all dependent measures. Neither the syntactic nor the semantic factor approached significance in the other regions ($Fs < 2$), except in the case of total reading times.

Table 1. Analyses of Mean First-fixation Durations, Gaze Durations, Regression-path Durations, Probability of First-pass Regressions, and Total Times at the conjunction (word 5) in Experiment 1.

Reading times analysis	*F1 (df)*	*F2 (df)*	*p*
First-fixation Durations			
Structural Ambiguity	37.98 (1,28)	45.82 (1,36)	< .01
Plausibility	46.75 (1,28)	36.91 (1,36)	< .01
Ambiguity x Plausibility	5.53 (1,28)	7.82 (1,36)	< .01
Gaze Durations			
Structural Ambiguity	44.25 (1,28)	61.64 (1,36)	< .01
Plausibility	47.28 (1,28)	35.29 (1,36)	< .01

Ambiguity x Plausibility	9.51 (1,28)	15.76 (1,36)	$< .01$
Regression-path Durations			
Structural Ambiguity	27.54 (1,28)	42.89 (1,36)	$< .01$
Plausibility	30.19 (1,28)	28.63 (1,36)	$< .01$
Ambiguity x Plausibility	13.51 (1,28)	9.92 (1,36)	$< .01$
Probability of First-pass Regressions			
Structural Ambiguity	44.35 (1,28)	27.38 (1,36)	$< .01$
Plausibility	30.46 (1,28)	20.88 (1,36)	$< .01$
Ambiguity x Plausibility	4.96 (1,28)	3.89 (1,36)	$< = .05$
Total Times			
Structural Ambiguity	74.40 (1,28)	111.96 (1,36)	$< .01$
Plausibility	85.43 (1,28)	58.36 (1,36)	$< .01$
Ambiguity x Plausibility	37.64 (1,28)	28.18 (1,36)	$< .01$

The measures of first fixation durations and gaze durations (Figures 2 and 3, respectively) allow examination of the earliest stage of processing. Processing difficulty was observed only at the conjunction. The interaction is manifested as a larger garden-path effect in the Strong RC-bias Ambiguous condition than in the Weak RC-bias Ambiguous condition. Nonetheless, pairwise comparisons confirmed that reading times were longer in both the Strong RC-bias Ambiguous condition (91 ms for first fixation durations and 110 ms for gaze durations) and the Weak RC-bias Ambiguous condition (38 ms for first fixation durations and 36 ms for gaze durations) compared to the unambiguous controls ($\alpha = .05$).
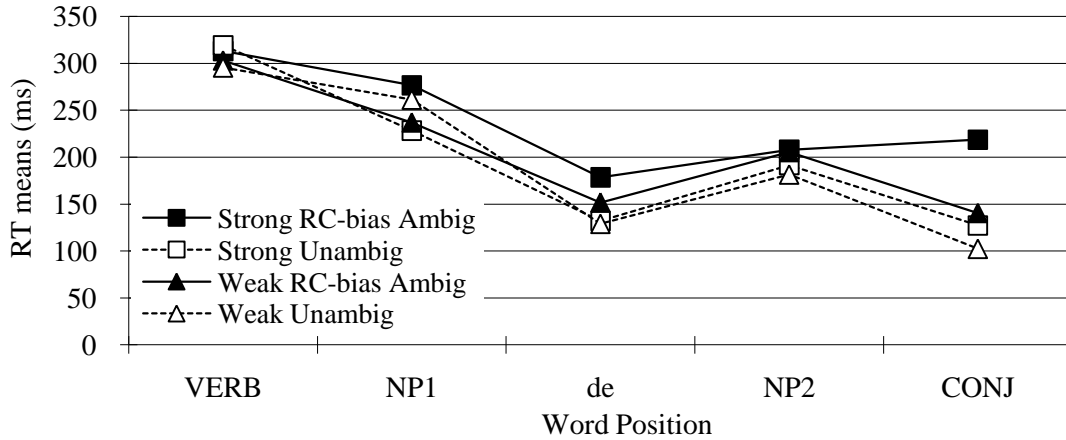
Figure 2. Means for first-fixation durations for each condition at each word position.
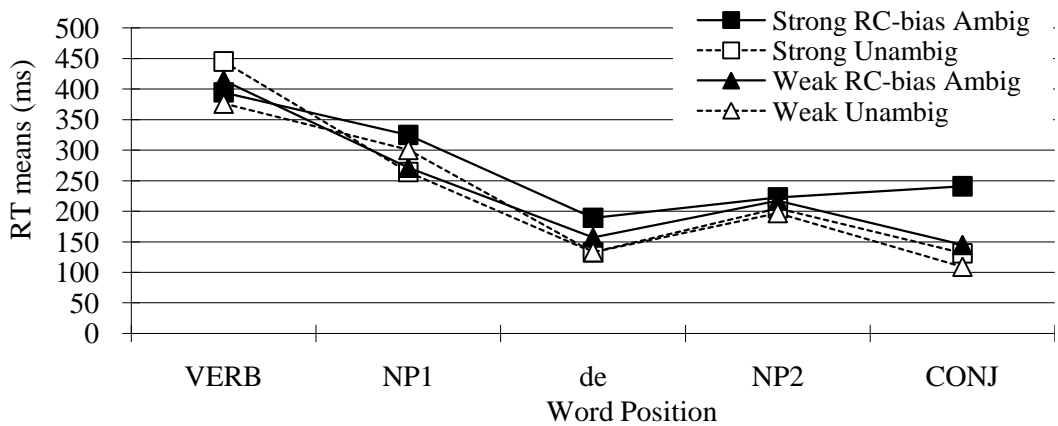
Figure 3. Means for gaze durations for each condition at each word position.

Regression path durations and probability of first-pass regressions often reflect re-processing after initial misanalysis has been detected (Staub & Rayner, 2007). Pairwise comparisons revealed that, on both measures, processing costs were substantially higher at the conjunction in the two ambiguous conditions than in the unambiguous control conditions ($\alpha = .05$). On regressive path durations (Figure 4), reading times were 598 ms and 210 ms longer in the Strong RC-bias Ambiguous and the Weak RC-bias Ambiguous con-

dition, respectively. Likewise, probability of first-pass regressions increased by 27% in the Strong RC-bias Ambiguous condition and 12% in the Weak RC-bias Ambiguous condition (Figure 5).
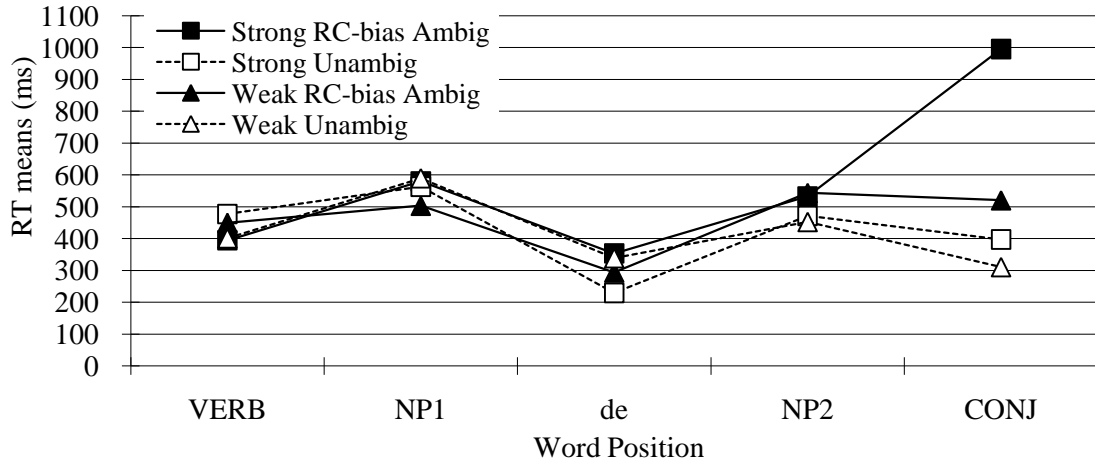
Figure 4. Means for regression-path durations for each condition at each word position.
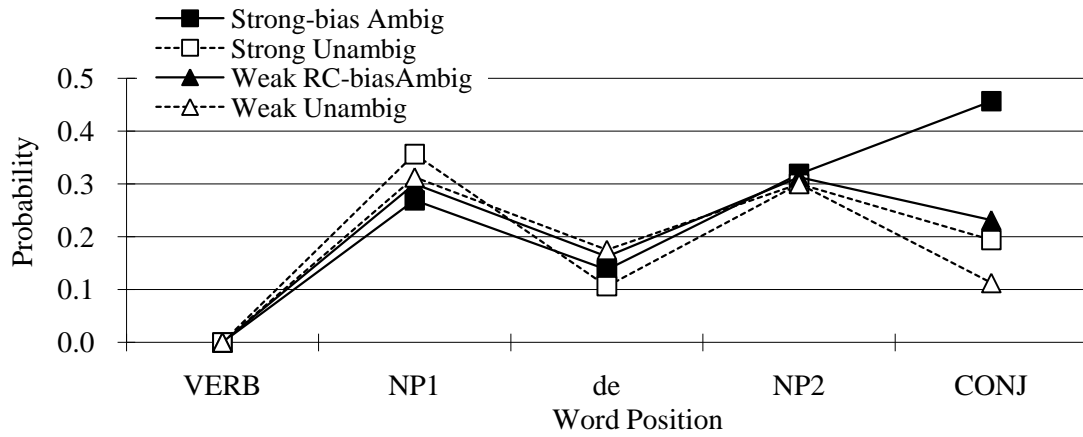
Figure 5. Means for the probability of first-pass regressions for each condition at each word position.

Total times (Figure 6), as a global measure of processing difficulty, sum up all initial and secondary fixation durations in a region. Thus, processing difficulty tied to secondary fixations in the Strong RC-bias Ambiguous condition are obvious throughout the ambiguous and disambiguating regions in Figure 6. Pairwise comparisons demonstrated that reading times were significantly longer at word 5 in both the Strong RC-bias Ambiguous (311 ms) and the Weak RC-bias Ambiguous (103 ms) conditions relative to the unambiguous counterparts ($\alpha = .05$). Moreover, total fixations were considerably longer at words 2-4 in the Strong RC-bias Ambiguous sentences than in the unambiguous counterparts. A reliable, yet smaller, increase in reading times was observed at *de* and NP2 for the Weak RC-bias Ambiguous sentences compared to the unambiguous controls. This again suggested that the initial garden-path effect and the reanalysis difficulty were reduced when the semantic support for the preferred RC structure was relatively weak.
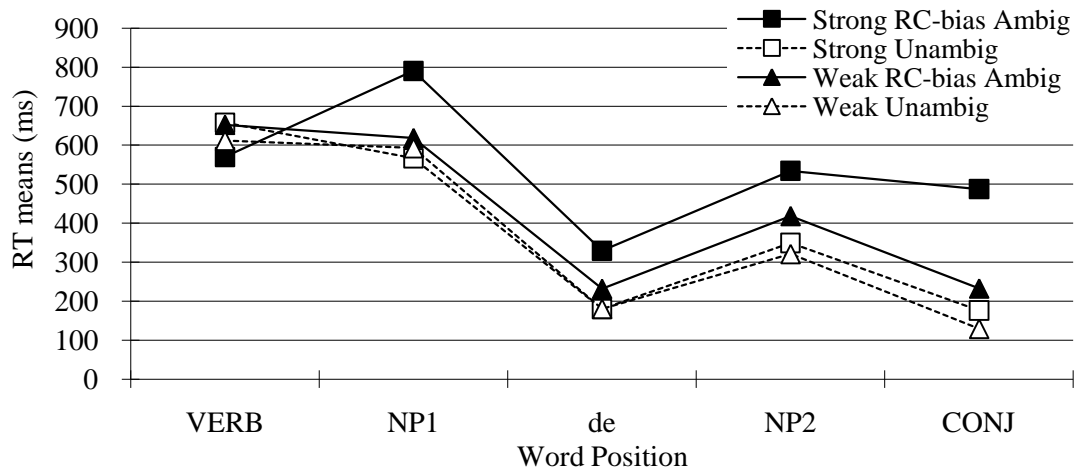
Figure 6. Means for total times for each condition at each word position.

In all dependent measures processing costs were much greater in the Strong RC-bias Ambiguous sentences than in the Weak RC-bias Ambiguous sentences. Apparently, it

was easier to re-rank the alternatives or recover from a misanalysis in the Weak RC-bias Ambiguous condition compared to the Strong RC-bias Ambiguous condition.

3.2.5 Discussion

Both the Strong RC-bias Ambiguous and the Weak RC-bias Ambiguous conditions exhibited a garden-path effect, reflected in increased reading times and more regressive eye movements at the disambiguating conjunction in comparison with the unambiguous controls. Crucially, processing costs were higher in the Strong RC-bias Ambiguous condition than in the Weak RC-bias Ambiguous condition when the dispreferred CC analysis was required at disambiguation. The findings are consistent with a limited, ranked model that predicts that processing difficulty arises when a structure of low availability has to be elevated to the top-ranked status. Reranking was more costly in the Strong RC-bias Ambiguous condition because the required CC interpretation received little support from the syntactic and the semantic constraints and thus became relatively inaccessible. On the other hand, the CC structure, although lower-ranked, remained relatively active in the Weak RC-bias Ambiguous condition given the balanced semantic information.

Our findings suggest that the activation level of structural alternatives varies as a function of the strength of support from the relevant constraints (e.g. McRae et al., 1998). Even though the RC and the CC analyses were maintained for the same number of words (i.e. up to the disambiguation at word 5), the difference in activation between the two alternatives was exaggerated in the Strong RC-bias Ambiguous sentences as the RC structure received overwhelming support from the available constraints. On the other hand, the strengths of the higher- and lower-ranked readings were closer in the Weak RC-bias Ambiguous items.

Serial parsing systems such as the Diagnosis model and SNIP cannot account for the differential processing cost in the Strong and the Weak RC-bias Ambiguous sentences, although the models correctly predict that the non-local structural revision would induce difficulty in both conditions. The serial repair models assume that a repair process is triggered by structural inconsistency and is performed through detaching and reattaching constituents. Meanwhile, the cost of structural repair is determined by how detectable the misanalysis is (Fodor & Inoue, 1994) or how effective the syntactic cue is in signaling the misanalysis (Lewis, 1998). This cannot explain the differential processing difficulty in the Strong and the Weak RC-bias Ambiguous sentences because the structural disambiguation (i.e. the conjunction at word 5) was consistent across the two conditions, and the misanalysis in the initial parse (i.e. *de* being erroneously analyzed as a RC maker) should be equally visible or invisible.

One might argue that, although the disambiguating cue had the same efficacy in signaling the misanalysis, some other aspect of ambiguity resolution or reanalysis was more costly in the Strong RC-bias Ambiguous sentences due to the overwhelming preference for the incorrect RC alternative prior to disambiguation. I consider two versions of this proposal. The first version harkens back to the thematic processer postulated by proponents of the garden-path model as a way to incorporate thematic role constraints into reanalysis, because the first-pass parse was assumed to be blind to semantic information (Rayner, Carlson, & Frazier, 1983; Ferreira & Henderson, 1991b). According to the thematic processer proposal, reanalysis was predicted to be easier if thematic constraints supported the structural revision. This theoretical division of labor, with semantic constraints ignored during the initial analysis, is no longer as popular as it once was. None-

theless, consider a serial parser that always constructs the RC structure, based solely on Minimal Attachment (Frazier, 1978), and reanalyzes at the disambiguating conjunction, guided by a thematic processor. If it is easier to assign the role of being comforted to the relative in (10a) than the role of trainee to the general in (9a), then the data pattern observed would indeed be predicted. However, the garden path model could not account for both the current data and the data from the closely related experiments in Hsieh et al. (2009), described above. In those experiments, there were no garden path effects in sentences like (5a) even though the minimal attachment analysis had to be revised. Thus, there is no version of the garden path model that can explain all, or even most, of the data for the RC/CC ambiguity in Chinese.

Could current serial/reanalysis models predict that reanalysis costs should be less in our Weak RC bias condition than in our Strong RC bias condition? Such a prediction would have to assume that the parser is sensitive to the strength of the constraints introduced during the ambiguous region. But to the contrary, even a constraint-based version of a serial parser would not have access to the biasing material within the ambiguous region if it was behaving in a deterministic serial manner. As illustrated above in Figure 1, parsing commitments would be made at NP_1 and *de* that allow only the RC interpretation to be evaluated at NP_2, where the semantic bias toward the RC is increased in the Strong RC-bias condition. In short, a parser that does not have access to the dispreferred structure cannot accommodate the differential revision cost in the two Ambiguous conditions.

While my findings were inconsistent with a serial repair account, I considered the possibility that the parser might sometimes initially adopt the correct, although dispreferred, CC reading in the Weak RC-bias Ambiguous sentences given the rather balanced

evidence for the two interpretations. Average revision difficulty would be smaller if the correct parse has been built some portion of the time. The serial variable-choice account proposes that when confronted with the ambiguous homograph *de*, the parser chose either the RC or the CC analysis, depending on the amount of supporting information. In the Strong RC-bias Ambiguous condition, the RC structure would be chosen as it had received strong support. In the Weak RC-bias Ambiguous condition, however, the CC reading might sometimes be adopted, since the RC alternative was not so strongly favored.

To explore this possibility I conducted a follow-up experiment using sentences that contained the same ambiguity but were disambiguated as a RC structure at a verb (word 5). If the CC interpretation has been chosen during the ambiguous region of the Weak RC-bias Ambiguous sentences, processing difficulty should arise when the initial parse proves to be inconsistent with the disambiguating material. On the other hand, the limited, ranked parallel model would predict no difficulty at disambiguation because the RC structure was favored, although to a different degree, in both the Strong and the Weak RC-bias Ambiguous items. Thus, no reranking would be necessary.

3.3 Experiment 2

Experiment 2 is similar to Experiment 1, but resolves the RC/CC ambiguity in the opposite direction. In Experiment 1, all the critical sentences were resolved as the dispreferred CC at word 5. In Experiment 2, all the critical sentences are resolved as the preferred RC. Example sentences are given below in (11) and (12).

3.3.1 Method

Thirty-two native Mandarin Chinese speakers from Taiwan were recruited from the University of Michigan community. These participants were not involved in Experiment 1.

Materials

As in Experiment 1, 40 sets of critical items were typed in traditional Chinese characters with 20 sets in each of the Strong RC-bias Ambiguous and the Weak RC-bias Ambiguous versions. The Ambiguous items contained the same ambiguous strings as in Experiment 1, thus the plausibility norms collected for Experiment 1 apply again here as a measure of the semantic bias during the ambiguous region. Because the disambiguation is always to the RC, new Unambiguous control sentences were constructed.

The critical change in the current experiment was that the ambiguous strings were followed by a verb that forced disambiguation towards the RC structure. The disambiguating verb was then followed by a complement at the end of the sentences. Moreover, a time adverbial was added at the beginning of the Ambiguous sentences, prior to the ambiguous strings. While the additional time adverbial did not affect the target ambiguity, it allowed the Ambiguous items to have a form parallel to the Unambiguous controls, which were exactly the same as their Ambiguous counterparts except that a definite article *the* appeared at the beginning of the Unambiguous sentences, forcing the RC interpretation of the following string.

Experiment 2 consisted of four types of sentences: Strong RC-bias Ambiguous (11a), Weak RC-bias Ambiguous (12a), as well as two Unambiguous controls (11b) and (12b). All critical sentences were 7 words long plus a period at the end, and were displayed in

one line on the computer screen. The ambiguous and the unambiguous sentences differed only at the first word. In addition, the forty critical items were interspersed with eighty fillers, including twenty ambiguous sentences that had the same structure but with various degrees of CC bias, and another twenty unambiguous sentences. The remaining forty fillers were of various types.

11.

(a) *Strong RC-bias Ambiguous*

meitian [xunlian shibing de jiangjun] daibing henfuze.

every day [train soldier RC general] lead very responsibly

A [general who trains soldiers] every day leads very responsibly.

(b) *Strong Unambiguous*

nage [xunlian shibing de jiangjun] daibing henfuze.

the [train soldier RC general] lead very responsibly

The [general who trains soldiers] leads very responsibly.

12.

(a) *Weak RC-bias Ambiguous*

meitian [anwei bingren de jiashu] juyou tonglixin.

every day [comfort patient RC family member] have empathy

A [family member who comforts patients] every day has empathy.

(b) *Weak Unambiguous*

nage [anwei bingren de jiashu] juyou tonglixin.

the [comfort patient RC family member] have empathy

The [family member who comforts patients] has empathy.

Procedure

The procedure was the same as that in Experiment 1.

3.3.2 Results

Eye-movement data were collected for all the 7 word positions in the critical items, with the critical region located at the disambiguating verb (word 6), where the serial variable-choice and the ranked parallel models made different predictions concerning whether processing difficulty would be present. The same five dependent measures (Figures 7-11) as those used in Experiment 1 were calculated for the critical verb region. For each dependent measure, the condition means were computed and entered into separate 2 (list) x 2 (structural ambiguity) x 2 (semantic bias) repeated measure ANOVAs, both by participants and by items.

A summary of the analyses is shown in Table 2. Reading times at the verb region were not longer in the Strong and the Weak RC-bias conditions, compared to their unambiguous counterparts. This was confirmed by paired comparisons (α = .05 by both participants and items). The ANOVAs revealed neither significant effects of structural ambiguity and semantic bias nor any interactions between the two factors (Fs < 3). No effects of structural ambiguity and semantic bias were significant in the other regions of the sentences (Fs < 2).

Table 2. Analyses of Mean First-fixation Durations, Gaze Durations, Regression-path Durations, Probability of First-pass Regressions, and Total Times at the verb (word 6) in Experiment 2.

Reading times analysis	*F1 (df)*	*F2 (df)*	*p*
First-fixation Durations			
VERB			
Structural Ambiguity	.08 (1,28)	.28 (1,36)	> .10
Plausibility	1.12 (1,28)	1.20 (1,36)	> .10
Ambiguity x Plausibility	2.09 (1,28)	.05 (1,36)	> .10
Gaze Durations			
VERB			
Structural Ambiguity	.39 (1,28)	.36 (1,36)	> .10
Plausibility	.08 (1,28)	.29 (1,36)	> .10
Ambiguity x Plausibility	.11 (1,28)	.33 (1,36)	> .10
Regression-path Durations			
VERB			
Structural Ambiguity	.23 (1,28)	.01 (1,36)	> .10
Plausibility	.23 (1,28)	.00 (1,36)	> .10
Ambiguity x Plausibility	.59 (1,28)	2.96 (1,36)	> .10
Probability of First-pass Regressions			
VERB			
Structural Ambiguity	.81 (1,28)	.14 (1,36)	> .10
Plausibility	.04 (1,28)	.06 (1,36)	> .10
Ambiguity x Plausibility	.36 (1,28)	.41 (1,36)	> .10
Total Times			
VERB			
Structural Ambiguity	.26 (1,28)	.06 (1,36)	> .10
Plausibility	2.38 (1,28)	.02 (1,36)	> .10
Ambiguity x Plausibility	2.70 (1,28)	.63 (1,36)	> .10
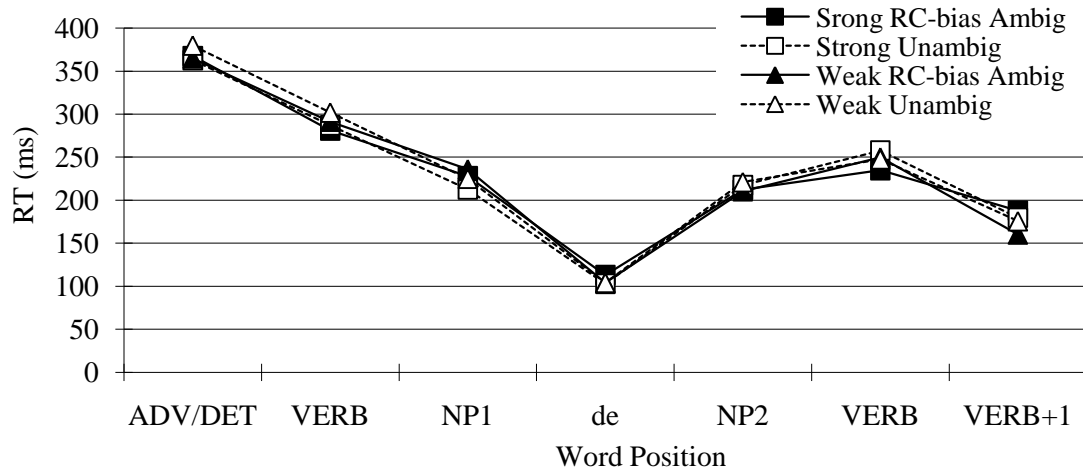
Figure 7. Means for first-fixation durations for each condition at each word position.
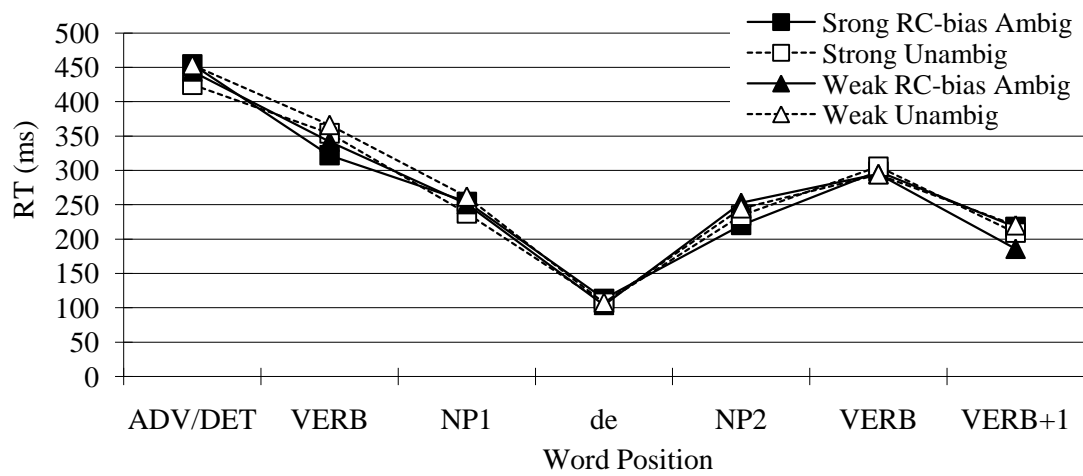
Figure 8. Means for gaze durations for each condition at each word position.
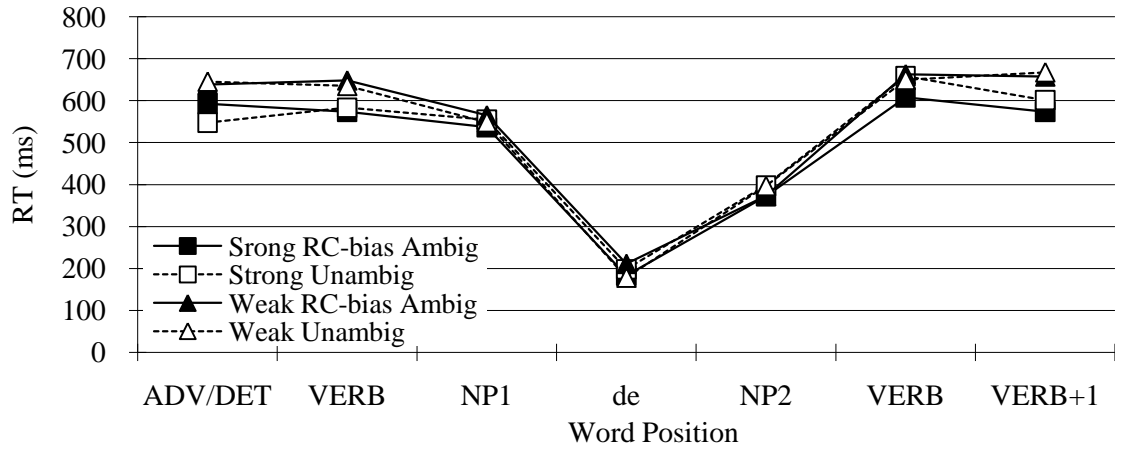
Figure 9. Means for regression-path durations for each condition at each word position.
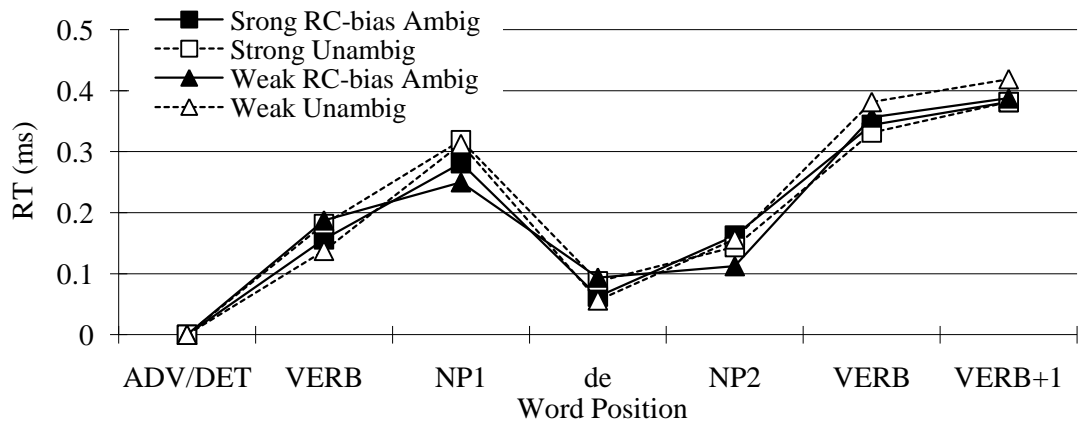
Figure 10. Means for the probability of first-pass regressions for each condition at each word position.
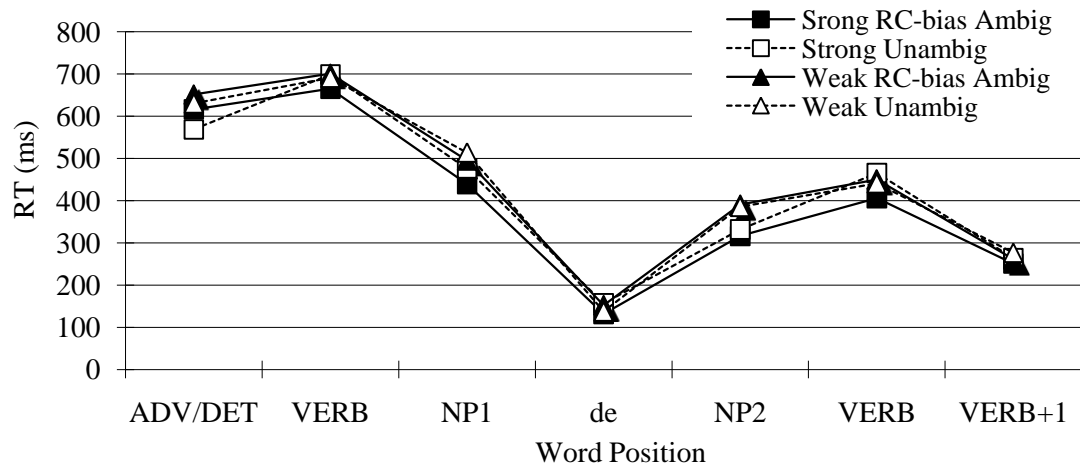
Figure 11. Means for total times for each condition at each word position.

3.3.3 Discussion

Experiment 2 investigated whether the dispreferred CC structure might sometimes be initially adopted in the Weak RC-bias sentences due to balanced semantic support, as would be possible under the serial variable-choice model. No processing difficulty occurred at the disambiguating verb, which was only compatible with the RC analysis of the ambiguous string. The results ruled out the possibility that the smaller difficulty observed in the Weak RC-bias sentences in Experiment 1 resulted from the selection of the correct CC structure during the initial parse.

Instead, the findings proved to be consistent with the predictions of the limited, ranked parallel account, which suggests that processing difficulty is associated with structural reranking, especially when a structure of low availability has to be reactivated. Under this account, no processing difficulty should occur in either the Strong RC-bias or the Weak RC-bias sentences because the correct RC analysis had already been ranked higher

than the CC alternative during the ambiguous region. Thus, no reranking would be necessary at the disambiguating verb.

3.4 General Discussion

Experiments 1 and 2 were designed to investigate whether the degree of processing difficulty at disambiguation was determined by the relative support for the structural alternatives of the RC/CC ambiguity *Verb NP$_1$ de NP$_2$*. The findings suggest that both the RC and the CC analyses were retained up to disambiguation and were ranked based on the supporting evidence from the relevant constraints. Crucially, processing difficulty varied as a function of the cumulative support for the dispreferred CC structure at disambiguation. Experiment 1 showed that processing difficulty was less when the RC and the CC interpretations were supported to a similar degree than when the higher-ranked RC was strongly favored over the CC alternative. The findings support a limited, ranked parallel account, such as the Gibson (1991) model, the Surprisal theory (Hale, 2001), or the SOPARSE model (Tabor & Hutchins, 2004).

The current experiments build upon similar experiments reported by Hsieh et al. (2009). As in Experiment 1, all critical items in Hsieh et al. were disambiguated to the dispreferred CC analysis. Nonetheless, Hsieh et al. (2009) found no evidence of any processing costs if the ambiguous region was short and some support was maintained for both analyses throughout the ambiguous region, as in (5a) above. Although the current experiments were not designed to test the length effect on processing difficulty, it is difficult not to compare the Weak RC-bias Ambiguous condition from the Experiment 1 (11a) with Hsieh et al.'s Inanimate Ambiguous condition (5a). Although the semantic disambiguation in Hsieh et al. and the syntactic disambiguation in Experiment 1 both required

the dispreferred CC structure that was incompatible with the initially preferred RC analysis, the disambiguating material appeared at different word positions. The difference in word position could explain why reranking was cost-free in Hsieh et al., while it incurred a small cost in Experiment 1. The longer ambiguous region in Experiment 1 might reinforce the difference in activation strength between the RC and the CC interpretations, which then enhanced the difficulty of structural revision.

As in Hsieh et al. (2009), reading times in Experiments 1 and 2 were not elevated during the ambiguous region compared to the comparable region of the unambiguous conditions. As argued by Gibson and Pearlmutter (2000), maintaining multiple structures does not necessarily result in a slowdown in processing. While Lewis (2000) claimed that highly ambiguous materials (e.g. an ambiguous sentence that had eight possible interpretations) could induce processing difficulty due to memory overload, the target construction in our experiments is only ambiguous in two ways. Thus, retaining both structures might never exceed memory limits. In fact, Green and Mitchell (2006) demonstrated that simultaneous activation of the two equally supported analyses of a global ambiguity did not lead to increased processing time relative to a disambiguated sentence. In other words, the maintenance of multiple structures alone is not directly associated with processing costs.

In conclusion, our findings can be best accounted for by a limited, ranked parallel account, which predicts high processing costs when a lowly activated analysis has to be recovered. As the supporting evidence strengthens the preference for the ultimately incorrect structure, the recovery of the dispreferred analysis becomes costly. A parallel parser that adjusts the activation of alternative structures based on the support from the input

constraints provides a unifying mechanism to account for differential processing difficul-

ty.

Chapter 4

The Effect of Lexical Repetition on Syntactic Priming: Evidence from Chinese Sentence Comprehension

4.1 Introduction

Syntactic priming has been used to investigate syntactic processes. Most work on syntactic priming has been concerned with sentence production. Bock and colleagues found syntactic priming in production using various structures and experimental tasks (e.g. Bock, 1986; Bock & Loebell, 1990; Bock et al., 1992). In a picture description task, for example, participants typically read or listen to alternating dative forms (i.e. prepositional datives vs. double-object datives) or alternating transitive forms (i.e. passives vs. actives) during the prime trial(s), followed by pictures that can be described with either one of the targeted structural alternatives. It has been found that prior exposure can facilitate the processing of a particular syntactic structure (see Pickering & Branigan (1999) for an overview).

Research using syntactic priming has provided strong evidence for representations of constituent structure during sentence production. Importantly, priming of syntactic representations does not result from lexical, metrical, semantic, or discourse similarities between prime and target (e.g. Bock, 1986, 1989; Bock & Loebell, 1990; Pickering & Bra-

nigan, 1998). Bock and Loebell (1990) showed that prepositional locatives (e.g. *The wealthy widow drove an old Mercedes to the church.*) primed prepositional datives (e.g. *The wealthy widow gave an old Mercedes to the church.*), despite the differences at the semantic and conceptual level. On the other hand, prepositional datives (e.g. *Susan brought a book to the student.*) did not prime infinitive structures (e.g. *Susan brought a book to read.*), which have different syntactic structure.

Recently, studies also demonstrate a preference for structural repetition in sentence comprehension. However, although syntactic priming is robust and independent of lexical repetition in language production, the effect has been found weaker and lexically specific in comprehension (Pickering & Ferreira, 2008). Research on comprehension priming typically uses locally ambiguous sentences to test for priming effects with the prediction that previous exposure to the dispreferred structure of a syntactic ambiguity should facilitate the processing of target sentences at the disambiguation point, where the primed analysis is required. The facilitated processing could be due to the enhanced activation of the dispreferred alternative prior to the point of disambiguation. Tooley et al.'s (2009) eye-tracking data showed that total reading times on the disambiguating region (i.e. the prepositional phrase) were reduced when the target sentences (e.g. *The spy caught by the FBI agent disappeared forever*.) followed a prime (e.g. *The criminal caught by the detective was in a state of panic*.) with the same verb. The linking assumption between reading time data and syntactic priming is that prior experience with a dispreferred structure (e.g. a reduced relative clause) could reduce reading times at disambiguation. One possibility is that syntactic priming in comprehension could increase the availability of the primed structure during the ambiguous region, which thus reduces the selection difficulty at dis-

ambiguation. Under a constraint-based lexicalist account of parsing (e.g. MacDonald et al., 1994), when repeated words are accessed during the comprehension of the target sentences, activation spreads to the syntactic structures that are bound to the activated lexical items. On the other hand, a non-lexicalist approach maintains that syntactic structures are not bound to specific words. The enhancement of the activation of the primed structure need not be accomplished by reaccessing the lexicon. Syntactic priming could occur at the functional level of syntactic representation and facilitate recovery of the ultimately correct structure. However, it is unclear how syntactic priming affected reading time during the ambiguous region in Tooley et al., given that the ambiguous region was short and that the verbs were identical or synonymous between the primes and the targets. Although Tooley et al. did find reduced first-pass times and total times at the repeated and the synonymous verbs respectively in the target sentences, the effects were likely to reflect semantic rather than syntactic priming.

Unlike production priming studies, this line of research has yielded inconsistent priming effects. In many cases, syntactic priming was found only when the verb is repeated between prime and target, although a few recent studies did report comprehension priming without verb repetition. The discrepancy between syntactic priming in production and comprehension gives rise to the debates regarding whether sentence comprehension is lexically driven.

The lexicalist theories of sentence comprehension (e.g., MacDonald et al., 1994; Trueswell & Tanenhaus, 1994) propose that sentence comprehension is guided by lexically specific syntactic information. Syntactic information is incorporated in lexical representations and thus can be accessed during word retrieval. More specifically, syntactic

information is encoded in lexical items (Hartsuiker et al., 2004; Levelt et al., 1999; Pickering & Branigan, 1998; Roelofs, 1992). The lemma level contains lemma nodes that represent the base form of a word (e.g. *give*) and syntactic information nodes that are linked to the lemma nodes. The syntactic information nodes specify the syntactic category (e.g. verb) and other syntactic properties, such as tense, person, and number, of the word. Furthermore, Pickering and Branigan (1998) proposed that the information of argument structure is also encoded in verbs. Thus, the activation of a verb would spread to the associated argument structure as well as the other syntactic features.

On this view, prior exposure to a verb in a particular syntactic context strengthens the connection between the verb and the appropriate syntactic structure. Thus, when the same verb is repeated in subsequent sentences, the associated structure would be primed and becomes more readily available than the alternatives. In other words, syntactic priming in comprehension is considered verb-specific and not involving the same representations as production priming, which is typically found lexically dependent.

Using a visual-world paradigm, Arai et al. (2007) indicated that syntactic priming in dative structure required verb repetition. When prime and target contained the same verb, double object primes facilitated subsequent double object structures. The eye-movement data showed that more and longer anticipatory looks were directed towards the potential recipient (relative to the theme) during the auditory presentation of the verb if the target sentences were preceded by a double object prime than by a prepositional prime. In other words, participants were anticipating a recipient immediately following the verb as in a double object dative structure after listening to a double object prime. No reliable priming occurred when the verb differed in prime and target. Arai et al. thus claimed that syntac-

tic priming in comprehension was verb specific. In addition, Melinger and Dobel (2005) demonstrated that a single verb presented in isolation was sufficient to prime a particular syntactic frame. Dutch and German native speakers were more likely to reuse the primed dative structure after being exposed to non-alternating ditransitive verbs that were restricted to either prepositional or double object dative construction, e.g., *contribute* only used in prepositional datives and *fine* only in double-object datives. Likewise, using a self-paced reading comprehension task, Trueswell and Kim (1998) found that prior exposure to verbs that tend to co-occur with either a sentence complement (e.g. *realized*) or a direct object (e.g. *obtain*) significantly enhanced the preference for the embedded subject analysis and the main clause object analysis of a temporarily ambiguous noun phrase, respectively, as *the fire* in *The photographer accepted the fire could not be put out* even if the target sentence contained a different verb. The results suggested that a verb's argument structure is lexically encoded and can be immediately used during syntactic ambiguity resolution.

The lexicalist account of syntactic priming is challenged by another line of evidence suggesting that syntactic priming is not driven by specific verbs. Instead, the tendency to repeat syntactic structure involves the preservation of syntactic configurations that are not associated with lexical items (Bock & Griffin, 2000). This is similar to the parallelism effect demonstrated by Frazier et al. (2000): the processing of coordinated structures is facilitated when the second clause repeats the syntactic structure of the first one. Bock and colleagues maintain that priming is a consequence of implicit learning processes, which cause long-term adaptation of the processing system. Under this account, the preference for a particular syntactic structure can be retained for long periods of time.

Chang et al. (2000) also proposes that prior exposure to a particular structure leads to the activation of a specific mapping between syntactic constituents and thematic roles. The message-to-syntax mapping then becomes more accessible compared to the other alternatives. From this viewpoint, syntactic priming in comprehension and production share similar abstract representations. During both comprehension and production priming, the processing system is tuned to compute the same mapping between message representations and syntactic configurations subsequently. Although there is not yet direct evidence for shared representations between language comprehension and production, it has been shown that representations developed during comprehension can facilitate subsequent production. Bock et al. (2007) demonstrated that the effect of comprehension-to-production priming was as robust as that of production-to-production priming. In particular, just listening to the prime sentences significantly increased the production of passive and prepositional dative structures subsequently.

Unlike Arai et al. (2007), Thothathiri and Snedeker (2008) found comprehension priming in dative structures without verb overlap between prime and target. In order to boost the priming effect, two primes were presented before the target, and the between-participant design was adopted, in which participants were only exposed to either prepositional dative primes or double-object primes to avoid interference from competing structures. The authors argued that although syntactic priming in comprehension might be relatively weak and needed to be boosted by repeated priming, comprehension priming was not lexically driven.

The findings in Thothathiri and Snedeker (2008) implied that the inconsistency of priming effects in comprehension might in part be due to the experimental methods. Un-

like in language production, readers have to integrate a variety of available constraints incrementally in order to discriminate the preferred analysis of a syntactic ambiguity. In other words, previous experience with a particular structure is not the only information that would guide syntactic analysis. Instead, it has to interact with other constraints, such as the relative frequency/complexity of competing structures (e.g. main clause vs. relative clause structure), the frequency of verb forms (e.g. past tense vs. past participle), and thematic fit among verb and arguments (e.g. the subject being a typical agent or patient/theme). Thus, a comprehension priming effect might be cancelled out by other constraints.

4.2 Experiment 3

Since the source of syntactic priming in sentence production and comprehension gives rise to different theoretical explanations regarding language processing and representation, further evaluation of the impact of lexical repetition on structural persistence is necessary. The goal of Experiment 3 was to replicate and extend the results of Thothathiri and Snedeker (2008) in a different experimental paradigm (i.e. self-paced reading) and a distinct structure (i.e. *Verb NP$_1$ de NP$_2$*). The question of whether comprehension priming could exist independent of lexical items is relevant to an ongoing debate in the literature about whether syntactic information is entirely encoded in individual words.

Using a self-paced reading paradigm, the study examined syntactic priming during the comprehension of the Chinese syntactic ambiguity, *Verb NP$_1$ de NP$_2$*, which is ambiguous between a relative clause (RC) structure and a complement clause (CC) structure. The ambiguity hinges upon the lexical ambiguity of the homograph *de*. For example, the first four words of (13) could mean either *the general who trains soldiers* (RC) with *de*

serving as a RC marker, or *to train the soldiers' general* (CC) with *de* being a genitive

marker. Hsieh et al. (2009) found that the RC was the preferred analysis, based on struc-

tural simplicity, semantic completeness, corpus statistics, and sentence completion data.

13.

xunlian shibing de jiangjun…

train soldier POSS/RC general…

train soldiers' general/(the) general who trains soldiers…

    The ambiguous construction, which had not been previously tested in the syntactic

priming literature, allowed us to investigate whether prior exposure to a particular struc-

tural alternative could affect the processing of the ambiguity in subsequent sentences.

The current experiment investigated the priming of the RC structure, the preferred analy-

sis of the target ambiguity, because Chinese RC structure has a different word order from

English RC structure, which allows for the examination of word order effect on bilingual

syntactic ambiguity resolution in a subsequent experiment. The hypothesis was that struc-

tural priming should enhance the preference for the primed analysis, which would incur

processing difficulty in the following target sentences when the unprimed alternative was

required at the disambiguation.

    Importantly, the verb and the head noun phrase differed between primes and targets in

the experiment. The prime sentences contained the construction of *Verb NP$_1$ de NP$_2$* pre-

ceded by the determiner *the*, forcing the RC interpretation of the ambiguity. The RC

analysis was then confirmed at the following verb, as shown in (14). The target sentences

were the Weak RC-bias Ambiguous items from Experiment 1. The RC and CC reading of the syntactic ambiguity were semantically and pragmatically balanced. In (15) it is almost equally plausible that a family member comforts a patient (RC) and that a patient's family member is to be comforted (CC). The syntactic ambiguity was then disambiguated towards the CC analysis at the following conjunction (i.e. *before/after/while*). In fact, Hsieh et al. (2009) found a small garden-path effect at the disambiguating conjunction, where the preferred RC structure had to be revised as a CC structure, even if the two alternatives received equal support semantically. Hsieh et al. argued that the structural revision did not lead to a severe garden path because the RC analysis was not strongly favored over the CC alternative due to the equal support from the semantic constraint.

(14) *RC Prime*

nage [xunlian shibing de jiangjun] daibing henfuze.

the [train soldier RC general] lead very responsibly

The [general who trains soldiers] leads very responsibly.

(15) *Target*

[anwei bingren de jiashu] zhihou, nage hushi likai le bingfang

[comfort patient POSS relative] after, that nurse leave PERF ward

After [comforting the patient's relative], the nurse left the ward.

In the current experiment, we investigated whether RC primes would reinforce the activation of the RC interpretation of the syntactic ambiguity in the subsequent target sen-

tences that contained different verbs and different head noun phrases. Since there was no content word overlap between the prime and the target sentences, any syntactic priming effects observed could not be attributed to lexical activation alone. Given their different assumptions about syntactic encoding, the residual activation account and the implicit-learning account make distinct predictions with respect to the processing difficulty at the disambiguating conjunction, where the RC analysis had to be revised as a CC structure.

4.2.1 Predictions

The implicit-learning account assumes that syntactic priming is not driven entirely by lexical items but involves abstract syntactic representations. Under this account, the parser should be able to use structural representations developed in the course of comprehension to guide the processing of subsequent sentences despite the absence of lexical repetition. Prior exposure to the RC primes should affect the parse of the local ambiguity in the target sentences. Specifically, the RC interpretation of the syntactic ambiguity should become more highly activated and deeply entrenched than the dispreferred CC analysis following the RC primes. Thus, structural revision at the CC disambiguation in the target sentences should induce greater processing difficulty when the RC primes were present than when they were absent.

On the other hand, the lexicalist account claims that syntactic priming is a consequence of residual activation of a lexical representation. If syntactic priming in comprehension is driven by specific verbs or head noun phrases, the RC primes should have no influence on the processing of the target ambiguity without a repetition of content words. In this case, structural revision from the RC to the CC interpretation at the disambiguation should be equally easy/hard in the primed and the unprimed condition.

4.2.2 Method

<u>Participants</u>

Twenty native speakers of Mandarin Chinese from the University of Michigan were paid a nominal sum to participate in the experiment. Although they also spoke English, Mandarin Chinese was the primary language they used outside of class.

Following Thothathiri and Snedeker (2008), we employed the between-participants design to maximize the possibility of detecting priming effects. Participants were randomly assigned to either the Prime or the No Prime condition. That is, half of the participants saw the prime sentences that contained the RC structure, and the other half did not. Given that syntactic priming can persist over several intervening items (Bock & Kroch, 1989; Bock & Griffin, 2000), in a within-participants design the effect of a prime on one trial might carry over to the subsequent trials even if the RC prime is not present. A between-participants design could magnify the difference between the Prime and the No Prime condition.

<u>Materials</u>

A total of 16 sets of critical items (see Appendix C) were typed in simplified Chinese characters. All critical items consisted of 4 sentences. In the Prime condition, the first two sentences were RC primes, and the last was the target sentence that contained the temporary ambiguity, *Verb NP$_1$ de NP$_2$*, and was then syntactically disambiguated towards the dispreferred CC interpretation at the following conjunction (i.e. *before/after/while*) followed by a comma. The prime and the target sentences were separated by one unrelated sentence in order to increase between-verb priming effects (Thothathiri & Snedeker, 2008; Konopka & Bock, 2005). The No Prime condition comprised exactly the same sentences

as those in the Prime condition, except that in the former the first two sentences had a simple SVO structure. Both the prime and the target sentences were 10 words long plus a period. An example of the Prime and the No Prime items were given in (16) and (17).

16. *Prime Condition*

Chinese Prime 1: nage [xunlian shibing de jiangjun] daibing henfuze.

               the [train soldier RC general] lead very responsibly

               The [general who trains soldiers] leads very responsibly.

Chinese Prime 2: nage [tongguo kaoshi de nuhai] jieshou daohe.

               the [pass exam RC girl] receive compliments

               The [girl who passed the exam] received compliments.

Chinese Filler: zhege wangzhan tigong shiyong zixun ji zhishi

               the website provide useful information and knowledge

               The website provides useful information and knowledge.

Chinese Target: [anwei bingren de jiashu] zhihou, nage ushi likai le bingfang

               [comfort patient POSS relative] after, that nurse leave PERF ward

               After [comforting the patient's relative], the nurse left the ward.

17. *No Prime Condition*

Chinese Non-prime 1: nage daoyan feichang shanchang zhidao nianqing yanyuan

               the director very good at guide young actor

               The director is very good at guiding young actors.

Chinese Non-prime 2: henduo zhiye nuxing rengran keyi jiangu jiating

               many career woman still can take care of family

Many career women can still take care of family.

Chinese Filler: zhege wangzhan tigong shiyong zixun ji zhishi

the website provide useful information and knowledge

The website provides useful information and knowledge.

Chinese Target: [anwei bingren de jiashu] zhihou, nage ushi likai le bingfang

[comfort patient POSS relative] after, that nurse leave PERF ward

After [comforting the patient's relative], the nurse left the ward.

In both conditions, the 16 critical items were pseudo-randomized with 48 filler sentences of various types and lengths with at least one filler intervening between every two experimental trials. One third of the fillers contained syntactic violations at different points in the sentences. All the sentences were displayed in one line on the computer screen.

Procedure

The experiment used a self-paced reading paradigm. Sentences appeared on a computer screen one word at a time in a moving window display. Participants were instructed to press the space bar to receive the next word. All times between presentation of a word on the screen and a response were measured to millisecond accuracy using E-Prime software. Each sentence was followed by a grammaticality judgment task, in which participants had to rate the grammaticality of the sentences on a 7-point scale. Before the experiment began, participants were provided with 6 practice sentences to familiarize them with the task.

4.2.3 Results

I analyzed reading times at each word position as well as the grammaticality ratings of the target sentences.

Word-by-word reading times provided an index of processing difficulty. Mean reading times were computed both by participants and by items. One-way ANOVAs were performed with "priming" as the experimental factor, which has two levels, Prime vs. No Prime. The statistical analyses at the conjunction and CONJ+1 showed an overall effect of priming. A summary of the analyses is provided in Table 3.

Table 3. Analyses of Reading Times at Each Critical Word Position in Experiment 3.

Reading times analysis	F1 (df)	F2 (df)	p
CONJ	5.66 (1,18)	3.61 (1,30)	$< .05, < .10$
CONJ+1	8.86 (1,18)	8.57 (1,30)	$< .05$

At the conjunction, the priming effect was significant by participants ($p < .05$) and marginally significant by items ($p = .07$). As shown in Figure 12, the reading times of the disambiguating conjunction, where structural revision occurred, were 178 ms longer in the Prime condition than in the No Prime condition. At CONJ+1, the priming effect was fully reliable both by participants and by items ($p < .05$). The reading times were 171 ms longer in the Prime condition than in the No Prime condition. Pairwise comparisons revealed no difference in reading times between the two conditions at the other word positions.
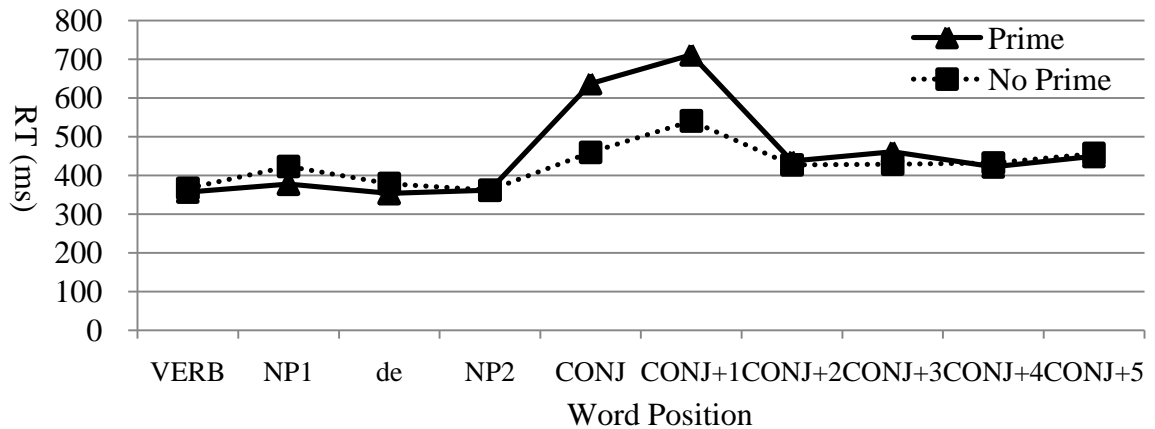
Figure 12. Mean reading times in ms for each condition at each word position in Experiment 3.

The mean grammaticality ratings of the target sentences were 4.6 in the Prime condition and 5.0 in the No Prime condition. Paired t-tests yielded no significant difference between the two conditions. In other words, the participant*s'* judgments were not affected by the presence/absence of RC primes. The target sentences did not receive lower ratings when preceded by RC Primes, although the target sentences were read slower at the conjunction and CONJ+1 during online comprehension. The rating associated with each sentence is provided in Appendix C.

4.3 Discussion

Syntactic priming effects have been less consistently observed in comprehension than in production, as comprehension priming is complicated by the influence of lexical overlap between prime and target. Despite the lack of verb repetition, reliable priming effects were demonstrated in comprehension using two primes and a between-participant design. The experiment replicated and extended the results of Thothathiri and Snedeker (2008) in a different experimental paradigm (i.e. self-paced reading) and a distinct structure (i.e.

Verb NP₁ de NP₂). As suggested in Thothatiri and Snedeker (2008), syntactic priming in comprehension might be relatively weak and needs to be boosted by repeated exposure to a particular structure. One explanation is that priming grows in strength over trials in an implicit learning process, which leads to increased accessibility of the primed structure. A non-lexicalist approach to parsing is supported by the finding that syntactic priming in comprehension did not reply on repeated verbs.

Specifically, structural revision from the RC to the CC structure induced greater processing difficulty at the disambiguating conjunction when the target sentences were preceded by RC primes than when there was no prime. Also, the significant slowdown at CONJ+1 was likely to result from a spillover from the disambiguation region. In the self-paced reading paradigm it is common that button presses advance rapidly beyond comprehension, resulting in additional processing in the subsequent region (Mitchell, 2004). Given that the position of CONJ+1 only contained a determiner *the*, the reading time increase in the Prime condition presumably reflected processing associated with the disambiguating conjunction in the earlier region.

The finding that syntactic priming increased the availability of the primed structure despite the lack of lexical repetition can be best accounted for by the implicit-learning account. Exposure to the RC primes facilitated the activation of the RC analysis of the syntactic ambiguity, which then became more accessible for subsequent processing relative to the CC alternative (Chang et al. 2000). During the process of implicit learning, the RC representation, which involves a particular mapping between thematic roles and syntactic constituents, was strengthened due to frequent use. Thus, it became costly when the particular message-to-syntax mapping had to be modified at the CC disambiguation,

where syntactic reconstruction and thematic role reassignment were triggered by structural incompatibility. On the other hand, the availability of the RC and the CC representation did not differ as much in the unprimed target sentences as they did in the primed items, although the RC is the preferred syntactic parse. We argue that syntactic priming in comprehension boosts the activation of abstract representations rather than just syntactic information associated with specific verbs.

The finding that the activation strength of structural alternatives of an ambiguity can be adjusted during syntactic priming suggested that previous experience with a syntactic structure functions as a constraint that could guide subsequent syntactic processing. Under the constraint-based approach (e.g. Spivey & Tanenhaus, 1998), multiple sources of constraints are immediately integrated during syntactic ambiguity resolution to discriminate the preferred analysis. Crucially, the activation level of structural alternatives is determined by the weighed sum of support from all available constraints. The preferred RC analysis of the ambiguity received higher activation in the primed condition, where both the experience and the syntactic constraint favored the RC structure, than in the unprimed condition, where the RC structure was supported only by the syntactic constraint. In other words, the accessibility of the RC structure is elevated due to prior exposure, making the recovery of the CC alternative difficult at the disambiguation point.

Unlike the current experiment that examined the priming of the preferred structure, most previous studies (e.g. Tooley et al., 2009) have attempted to prime the less preferred reduced RC against the main clause interpretation during the resolution of the main clause/reduced RC ambiguity (e.g. *The speaker proposed…*). While those studies typically did not find comprehension priming without lexical overlap between the prime and the

target, the result could be accounted for by the fact that the priming effect might have been cancelled out by the combined strength of the opposing cues. That is, the reduced RC structure might be hard to prime because of its lower frequency in English and relatively complex structure compared to the main clause alternative. The subject might also be a typical agent, supporting the main clause interpretation, rather than a typical patient/theme.

If we consider prior experience as a constraint on syntactic ambiguity resolution, the strength of support from this particular constraint could in part account for why Thothathiri and Snedeker (2008) found verb-independent comprehension priming with two primes while Arai et al. (2007) yielded no priming using only one prime. The strength of the constraint could be boosted through repeated exposure, making it a more effective cue in subsequent processing.

Although syntactic priming in comprehension occurred without content word overlap between the prime and the target, the experimental materials did not rule out a contribution from the function word *de*. Since the prime and the target sentences both contained the construction of *Verb NP$_1$ de NP$_2$*, they shared the function word *de*, which can be analyzed as either a RC marker or a possessive marker. Under a lexicalist account of parsing, the comprehension priming of the RC structure observed in the study could be attributed to the priming of the RC marker interpretation of *de*. It is possible that prior experience to the RC structure strengthened the link between the RC structure and the function word. Thus, when the repeated function word was encountered in the target sentences after a RC prime, the lexical activation spread to the associated RC structure, which then became much more readily available than the dispreferred CC alternative.

While lexical priming might be responsible for the activation of the RC representation, it is also possible that the priming effect occurred at the syntactic level, as the prime and the target sentences did share constituent structures. As demonstrated in Bock (1989) and Fox Tree and Meijer (1999), syntactic priming in production does not depend on function word repetition. For example, priming was found between "*A cheerleader offered a seat to her friend.*" and "*A cheerleader saved a seat for her friend.*"). Moreover, the presentation of *de* in isolation presumably would not be sufficient to prime the RC analysis of the syntactic ambiguity in the target sentences. In Chinese the function of *de* is completely context-dependent, and the word itself does not denote a particular syntactic structure. In fact, *de* can be used to introduce various modifying relations, where the modifier can be an adjective phrase, a noun phrase, or a verb phrase (Li & Thompson, 1981). Thus, it is unlikely that the priming of the RC structure was just due to residual activation of the lexical representation of the function word or that the priming only strengthened the link between *de* and the RC structure.

In short, the observed priming effect in the experiment reflected the enhanced activation of the primed RC structure, which made the recovery of the ultimately correct CC alternative more costly in the Prime condition than in the No Prime condition. Nevertheless, the current experiment did not provide straightforward answer regarding the mechanisms behind the activation of the RC structure. The priming of the RC structure in the target sentences after RC primes could be either due to lexical access of the repeated function word *de*, under a lexicalist account, or due to the activation of the shared constituent structure that was unbound to specific lexical items, under a non-lexicalist account. The lexicalist approach to parsing could be ruled out by the following experiment (Expe-

riment 4), where the priming of the RC structure was found between Chinese and English in the absence of identical lexical items.

In addition, the results in the current experiment did not provide direct answer to the question of whether the subject relative, *Verb NP$_1$ de NP$_2$*, can only be primed by an exactly the same syntactic structure. It is possible that subject relative clauses that contain an intransitive verb phrase (i.e. *Verb de NP*) would be sufficient to facilitate the processing of subject relatives with transitive verb phrases (i.e. *Verb NP de NP*) because the two structures have essentially the same constituent structure, namely VP RC NP. It is also not impossible that what is primed is modification of the head noun phrase, namely CP NP. Further investigation thus has to be conducted to clarify whether relative clauses that contain different types of modifiers can prime each other. Nevertheless, these unanswered questions do not undermine the argument that syntactic priming must involve non-lexicalized syntactic configurations.

In conclusion, the experiment showed that syntactic priming in comprehension enhanced the activation level of the RC analysis of the target syntactic ambiguity. The results provided evidence against a pure lexicalist account of syntactic representation, given that the priming effect was not verb-specific. Yet, it is necessary to further explore whether syntactic priming operates entirely at the level of abstract message-to-syntax representations or in part results from the priming of specific function words associated with syntactic structures. In addition, it is worth investigating whether comprehension priming must rely on repeated exposure to a structure, although this is beyond the scope of the current dissertation.

Chapter 5

The Effect of Word Order on Syntactic Priming in Comprehension:

Evidence from Chinese-English Bilinguals

5.1 Introduction

Recent studies have used syntactic priming to investigate online sentence processing in a bilingual context. Loebell and Bock (2003) showed that German-English bilinguals were more likely to describe a picture using a prepositional dative (e.g. *The boy sent a letter to his pen-pal.*) in one language after producing the same structure in the other language. Hartsuiker et al. (2004) also found that Spanish and English passive structures primed each other in production. While robust syntactic priming has been observed across languages with structures of the same word order, cross-language studies have yielded inconsistent findings regarding whether structures of different word order can prime each other. Experiment 4 investigated the effect of word order difference on cross-linguistic structural priming by examining the comprehension of the RC structure in Chinese and English, which differ in word order.

Cross-linguistic differences in word order have raised the important question of how bilinguals represent similar structures that have different word order in their two languages. Two models have been proposed based on different assumptions concerning whether

the construction of syntactic representations consists of one or two levels. The two-level model (e.g. Garrett, 1980; Kempen & Hoenkamp, 1987; Bock & Levelt, 1994) proposes that word order is specified in a linearization process that operates independently of the computation of constituent structures. On this view, syntactic construction consists of a functional level, at which structural (i.e., syntactic dominance) or functional relations are assigned, and a positional level, at which serial order is determined. One hypothesis of the nature of the functional level involves the argument-structure construction. According to Chang et al. (2003), an argument-structure construction is a scheme that maps an array of thematic roles to grammatical relations. For example, in the RC (18) *the general* is assigned the syntactic function of a subject and the thematic role of agent while *soldiers* functions as the object and receives the role of patient/theme.

18.

[The general who trained soldiers] was very responsible.

Chinese and English RC structures were identical with respect to functional and hierarchical relations between constituents, and only differ in word order. As shown in Figure 13, the RC analysis of the Chinese construction, *Verb NP$_1$ de NP$_2$*, involves the same mapping between grammatical and thematic roles as the corresponding English RC structure. *NP$_1$* is the object assigned the role of patient/theme, and *NP$_2$* is the subject bearing the agent role. The only difference between Chinese and English RC structures is the position of the head noun and the complementizer. In Chinese, the head noun appears after

the RC followed by the complementizer whereas the head noun and the complementizer precede the RC in English.

19.

[xunlian shibing de jiangjun] hen fuze

[train soldier RC general] very responsible

[The general who trained soldiers] was very responsible.

Under the two-level account, the shared components of Chinese and English RC structures are represented only once at the abstract, functional level whereas the additional language-specific information (e.g. word order) is consecutively computed at the positional level independently of the functional level. Figure 13 below illustrates the shared representations between Chinese and English RC structures. It is important to note that serial order is not specified at the functional level. Although the head noun appears before the RC in English and after the RC in Chinese, both structures contain an extracted subject noun phrase, which receives the agent role, and a modifying RC that contains a predicate and an object bearing the role of patient/theme.

```
   ┌─────────┐        ┌─────────┐
   │ Chinese │        │ English │
   └────┬────┘        └────┬────┘
        │                  │
   ┌────┴──────────────────┴────┐
   │ SUBJECT        OBJECT      │
   │    │              │        │
   │ NPᵢ  [eᵢ  VP  NP]          │   functional level
   │    │              │        │
   │ AGENT        PATIENT/THEME │
   └────┬──────────────┬────────┘
        │              │
   ┌────┴─────┐   ┌────┴──────┐
   │Head-final│   │Head-initial│  positional level
   └──────────┘   └───────────┘
```
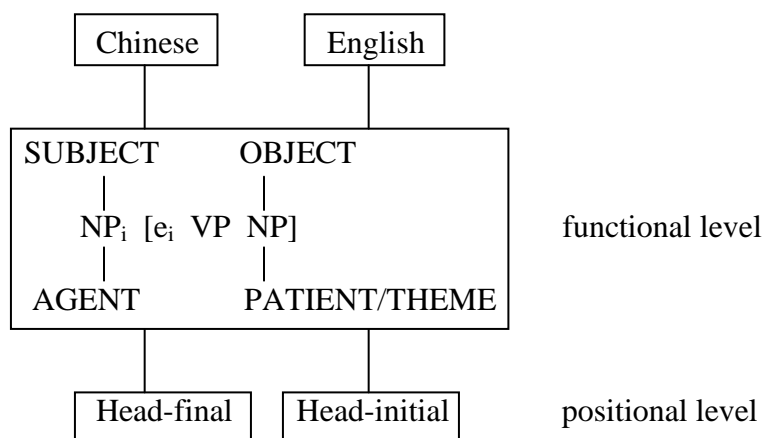
Figure 13. Illustration of syntactic representations of Chinese and English RC structures at the functional level and the positional level.

The two-level account of syntactic representations is consistent with a linguistic theory in which syntactic dominance relations are computed separately from precedence relations, such as Head-driven Phrase Structure Grammar (HPSG) (Pollard & Sag, 1987; Pollard & Sag, 1994; Sag et al., 2003). The framework of HPSG contains separate types of phrase structure rules to describe immediate-dominance and linear-precedence relations between constituents. The grammar displays dominance and precedence relations simultaneously but deals with the two aspects of structure separately. Under this account, our syntactic knowledge includes a functional representation of unordered constituent structures and a separate representation of surface orderings. The constituent order is stated for the grammar as a whole rather than on a rule-by-rule basis. Chinese, for example, is a SVO language with head-initial verb phrase structures but head-final RC structures, namely CP NP. English, on the other hand, is a consistent head-initial language, including RC structures, NP CP.

Unlike the two-level account, the one-level model of syntactic construction (e.g. Pickering et al., 2002) maintains that both functional and positional relations of constitu-

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ent structures are computed simultaneously in a single level. If the positional information of constituent structures is encoded along with the functional level of syntactic representation, Chinese-English bilinguals have separate representations of RC structures for each language given the different word order in the two languages.

Bilingual research has reported controversial findings supporting either the one-level or the two-level account. Bernolet et al. (2007) reported no priming between Dutch and English RC structures in spoken sentence production tasks, and argued that the two structures were represented separately due to different verb positions (e.g. *de baby die rood is* "*the baby that red is*"). In picture-description task, Loebell and Bock (2003) found syntactic priming between English and German dative structures. Prepositional datives and double-object datives each primed the corresponding structure that has the same word order. In contrast, no priming was observed between English and German passives, where word order differs with the main verb occurring in the sentence-final position in German. In addition, Pickering et al. (2002) argued that structures of different word orders must be represented separately based on the finding that English shifted datives (e.g. *The racing driver showed to the helpful mechanic the torn overall.*) and non-shifted datives, which only differ in word order, did not prime each other in the sentence completion tasks.

Desmet and Declercq (2006), however, did observe structural priming of the attachment of relative clauses to noun phrases from Dutch to English in a written sentence completion task despite different word orders. The high-attachment interpretation of English relative clauses (e.g. *The farmer fed the calves of the cow that were…*), where the RC was attached to the first noun phrase, *the calves*, was considerably more common follow-

ing Dutch high-attachment relative clauses (e.g. *De docent adviseerde de leerlingen van de lerares die…weren 'The lecturer advised the students of the teacher who…were'*). Likewise, Shin and Christianson (2009) demonstrated that Korean prepositional datives, which have the order of SOV with two different argument orders, elicited more production of English prepositional datives (e.g. *The lawyer gave a gift to the child.*). The findings provided evidence for an abstract, functional level of syntactic representation shared between languages, as cross-linguistic priming occurred between structures that share syntactic function, regardless of argument order.

5.2   Experiment 4

While the previous studies yielded controversial results regarding on the impact of word order on cross-linguistic syntactic priming, the effects have been investigated only in production tasks. The absence of the priming effect in Bernolet et al. (2007) and Pickering et al. (2002) might have resulted from the markedness of the RC structure and the shifted dative structure, respectively. Since the bilingual speakers in the studies might have been inclined to produce the less marked alternatives, the target constructions might have been hard to prime.

Using a self-paced reading task, the current experiment explored whether cross-linguistic syntactic priming can persist even with word order differences during sentence comprehension. In particular, the experiment investigated whether the preference for the RC interpretation of the Chinese syntactic ambiguity, *Verb NP$_1$ de NP$_2$*, would be boosted after an English RC structure was read. The target sentences were adopted from Experiment 3 and were disambiguated towards the dispreferred CC analysis at the conjunction following the ambiguity. As shown in Hsieh et al. (2009), the RC structure is the pre-

ferred analysis of the syntactic ambiguity, and a small garden-path effect was observed at the disambiguating conjunction, where structural revision from the RC to the CC interpretation was required. In the present experiment, processing difficulty in the disambiguating region of the target sentences was evaluated by comparing the reading times in the primed condition relative to the unprimed condition. The difference in processing difficulty between the two conditions presumably would reveal the effect of syntactic priming without the potential confound of the markedness and complexity of a particular structural alternative of the ambiguity. The hypothesis is that although Chinese and English RC structures differ in word order, the cross-linguistic priming should be as strong as the within-language priming effect observed in Experiment 3 if the two languages share a representation of syntactic information.

5.2.1 Predictions

The shared-syntax and the separate-syntax account make different predictions regarding whether English RC structure would prime the corresponding structure in Chinese.

The shared-syntax account proposes that bilinguals should have an integrated representation of Chinese and English RC constructions that share grammatical functions. In this view, cross-linguistic priming should occur despite the word order variation. Thus, the English RC primes in (20) below should strengthen the preference for the RC analysis of the syntactic ambiguity in the Chinese target sentences, which would increase processing difficulty at the CC disambiguation.

On the other hand, the separate-syntax account assumes that bilinguals represent the syntax of their languages separately. Chinese and English RC structures   might make these structures should receive separate syntactic representations due to word order dif-

ference. In this case, the presence of the RC structure in English should have no influence on the activation of the corresponding structure in Chinese. Thus, there should be no difference in reading times for the conjunction in the target sentences between the Prime and the No Prime condition.

5.2.2 Method

Participants

Twenty Chinese-English bilinguals were recruited from the University of Michigan community and were paid a nominal sum to participate in the experiment. All participants had been extensively exposed to both Chinese and English before the age of 12 and used both languages on a daily basis. As in experiment 3, participants were randomly assigned to either the Prime or the No Prime condition.

Materials

The target sentences were the same as those used in Experiment 3. The differences were that the primes were English sentences and that the fillers were half Chinese and half English. The English primes contained a RC structure with the relative pronoun *that*. As in Experiment 3, the prime sentences were 10 words long plus a period and the fillers were of various types and lengths. An example item is given below.

20. *Prime Condition*

English Prime 1: The professor who taught biology always stayed in the lab.

English Prime 2: Students who studied hard are likely to get good grades.

Chinese/English Filler: It is not easy to remove coffee stains from carpets.

Chinese Target: [anwei bingren de jiashu] zhihou, nage ushi likai le bingfang

[comfort patient POSS relative] after, that nurse leave PERF ward

After [comforting the patient's relative], the nurse left the ward.

21. *No Prime Condition*

English Non-Prime 1: The key was pretty rusty from many years of disuse.

English Non-Prime 2: Desert plants have adapted to the dry and hot weather.

Chinese/English Filler: It is not easy to remove coffee stains from carpets.

Chinese Target: [anwei bingren de jiashu] zhihou, nage ushi likai le bingfang

[comfort patient POSS relative] after, that nurse leave PERF ward

After [comforting the patient's relative], the nurse left the ward.

Procedure

The procedure was the same as that in Experiment 3

5.2.3 Results

As shown in Figure 14, the reading times were generally longer in this experiment than in Experiment 3. The Prime condition elicited greater processing difficulty only at the conjunction compared to the No Prime condition.

The conjunction was read 279 ms slower in the Prime condition than in the No Prime condition. One-way ANOVAs showed a significant effect of priming both by participants and by items. At CONJ+1, reading times were 100 ms longer when RC primes were present, but the priming effect did not reach significance (p = .20). The analyses are summarized in Table 4.
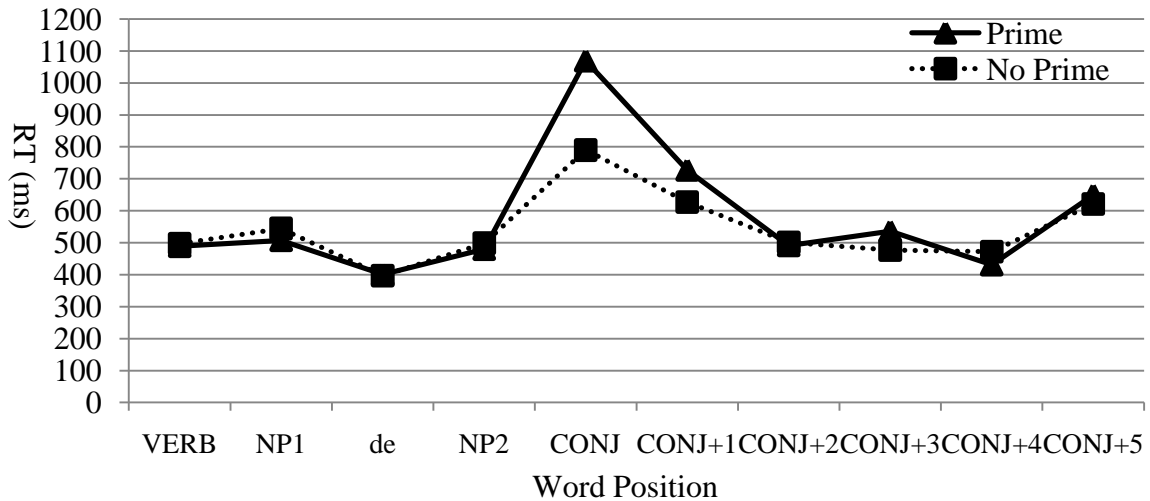
Figure 14. Mean reading times in ms for each condition at each word position in Experiment 4.

Table 4. Analyses of Reading Times at Each Critical Word Position in Experiment 4.

Reading times analysis	$F1 \ (df)$	$F2 \ (df)$	p
CONJ	4.98 (1,18)	5.02 (1,30)	$< .05$
CONJ+1	1.69 (1,18)	1.32 (1,30)	$> .10$

The target sentences received a mean rating of 4.7 in the Prime condition and 4.9 in the No Prime condition. The ratings were similar to those in Experiment 3. A t-test showed no reliable difference between the two conditions. The rating associated with each of the target sentences is provided in Appendix C.

5.3 Discussion

Consistent with the monolingual findings, the target sentences were read slower at the disambiguating conjunction in the Prime condition compared to the No Prime condition. That is, structural revision from the preferred RC to the CC analysis was more difficult when the Chinese target sentences were preceded by the English primes that contained a

RC structure. The data pattern suggested that English RC structure could prime the corresponding structure in Chinese during sentence comprehension despite word order difference. Crucially, the cross-linguistic priming effects cannot be attributed simply to lexical priming because the English primes and the Chinese targets did not contain translation equivalents except for the RC marker. The potential contribution of the function word to the priming effect has been discussed at the end of Chapter 4.

This is the first demonstration of comprehension priming of syntactic structures that have different word order across languages. Importantly, the priming effects were not associated with specific lexical entries, given that there was no lexical repetition between the English primes and the Chinese targets. The results provided supporting evidence for the shared-syntax account of bilingual representation as the preference for the RC structure can be primed from English to Chinese. We argued that the observed priming effects occurred because Chinese and English RC structures share the same function, although the word order is different. In other words, cross-linguistic priming does not require identical word order, since the functional and positional information of a syntactic construction presumably are computed separately.

Compared to the results obtained in Experiment 3, the participants in Experiment 4 generally read slower compared to those in Experiment 3, which was probably caused by the lower level of Chinese reading proficiency of the bilingual participants. Although the bilinguals had grown up speaking both languages, some of them had less extensive experience in Chinese reading. In addition, the data from Experiments 3 and 4 differed with respect to the processing difficulty observed at CONJ+1. While the effect of garden path was reliable at CONJ+1 in Experiment 3, the reading times at CONJ+1 was not signifi-

cantly longer in the Prime condition relative to the No Prime condition in Experiment 4. Since CONJ+1 were occupied by a high-frequency determiner, *the*, the elevations were likely to reflect a spillover effect from the disambiguation conjunction. One possible explanation of the relatively small spillover effect in Experiment 4 was that the bilingual participants might have finished most part of the processing before moving to the subsequent words, since they generally spent longer time on each word of the sentences, including the disambiguating conjunction, compared to the monolingual readers in Experiment 3. Another possibility was that the reading time difference between the Prime and the No Prime sentences did not really reflect the amount of processing difficulty incurred in the Prime condition because the study lacked an unambiguous baseline condition. While the design did not undermine the primary finding of the experiment regarding cross-linguistic syntactic priming, it was hard to determine whether the spillover effect was indeed smaller in Experiment 4 than in Experiment 3.

Although the data patterns of Experiments 3 and 4 revealed minor differences, cross-linguistic priming was obtained from English to Chinese RC structure. The experience with English RC primes strengthened the preference for the RC interpretation of the syntactic ambiguity in the subsequent Chinese target sentences. Due to the priming effect, the activation strength of the preferred RC analysis was much higher relative to the ultimately required CC reading, which then became hard to access at the CC disambiguation. In other words, the activation of English primes contributed to the difference in *activation* levels between the two structural alternatives of the syntactic ambiguity in the subsequent target sentences. On the other hand, the Chinese-English bilinguals were less committed to the RC structure when the RC primes were absent. For the unprimed items the RC re-

presentation was only favored by the syntactic (but not the semantic) constraint. Thus, structural revision from the RC to the CC analysis was then easier due to the relatively similar activation level of the two alternatives.

The finding favors the interactive view of bilingual syntactic processing, as exposure in one language affects the processing of the target syntactic ambiguity in the other language. While syntactic priming is sensitive to abstract structures, the priming process might also involve the activation of shared conceptual representations in Chinese and English (Griffin, 2003). It is difficult to entirely exclude the effect of conceptual priming as the process of language comprehension and learning must include conceptualization. Nevertheless, the observed structural persistence was not likely to arise simply from the conceptual level because the English primes and the Chinese targets described unrelated events involving different entities. The languages only shared thematic roles (i.e. an agent and a patient/theme) and syntactic constituents, and the conceptual roles must be mapped onto appropriate syntactic positions (i.e. agent to the extracted subject and patient/theme to the object position) in order to generate the RC representation. In other words, priming of the RC structure must be derived from the activation at both the conceptual and the syntactic level. Thus, a switch in structure, in this case from the RC to the CC analysis, requires a remapping process, and the cost associated with the revision varies as a function of the strength of the links between the corresponding elements.

In conclusion, we found that structural revision from the RC to the CC structure elicited greater processing difficulty when the target Chinese syntactic ambiguity were preceded by English RC primes than when there was no prime, suggesting that prior exposure to English RC structure facilitated the activation strength of the corresponding struc-

ture in English, despite word order difference. The cross-linguistic priming effect pro-

vided evidence for the shared-syntax account, which maintains that two languages have

an integrated representation of syntactic structures that involve the same mapping be-

tween syntactic and semantic levels. Importantly, syntactic priming occurs in the absence

of word order and content-word repetition (although possibly enhanced by function word)

appears to indicate that the representaiotn of syntactic information is at least partially

abstract and that word order is computed separtely from constituent structures.

Chapter 6

Conclusions

The dissertation examined theoretical and experimental aspects of syntactic processing in Chinese monolinguals and Chinese-English bilinguals. Using the ambiguous construction of *Verb NP₁ de NP₂* in Chinese, four reading time studies explored how a syntactic ambiguity is represented online and how syntactic and non-syntactic constraints are integrated during syntactic ambiguity resolution. The syntactic ambiguity, *Verb NP₁ de* NP₂, is ambiguous between a relative clause (RC) and a complement clause (CC) analysis. Crucially, the RC is the preferred analysis, based on structural simplicity, semantic completeness, corpus statistics (Zhang et al., 2000), and sentence completion data (Hsieh et al., 2009).

The temporary ambiguity hinges on the ambiguous function word *de*, which serves as a genitive marker in the CC analysis and a RC marker in the head-final RC interpretation. Crucially, the structures and thematic role assignments are very different, making cost-free reanalysis (in a serial parsing model) unviable. In earlier research (Hsieh et al., 2009), I showed that revision from the preferred RC to the CC structure became more difficult the longer the RC analysis continued to receive support. Resolving the ambiguity as the less preferred CC was costly under some conditions but not under others. We took this as evidence for a limited parallel processor, such as Tabor and Hutchins' (2004) SOPARSE,

which maintains multiple syntactic analyses across several words of a sentence when the structures are each supported by the available constraints.

Built on the findings in Hsieh et al. (2009), the four experiments in the dissertation provided evidence for a constraint-based parallel parser. In terms of parallel parsing, the eye-tracking data in Experiments 1 and 2 supported a limited, ranked parallel account. Hsieh et al. revealed that processing difficulty associated with structural revision is sensitive to the length of the ambiguous region. Disambiguation to the dispreferred CC analysis was more difficult as the RC analysis received support one word longer. As argued in Tabor and Hutchins (2004), the preferred RC structure grew in strength over time while the accessibility of the CC alternative decreased due to lack of support. However, although the length of the ambiguous region can increase the cost of structural revision, it is likely that disambiguation difficulty can differ even if the length is held constant.

In Experiments 1 and 2, disambiguation to the CC always occurred at the conjunction, but the degree of semantic support for each analysis was manipulated during the ambiguous region. The main goal was to explore whether the difficulty of structural revision could be predicted only based on in a constraining context with the length of the ambiguous region held constant. Experiment 1 demonstrated that the degree of processing difficulty varied as a function of the relative support for the RC and the CC interpretation from the syntactic and the semantic constraints. Greater processing difficulty arose at the disambiguation when the RC reading was much more strongly supported by semantic cues relative to the CC alternative, than when the two analyses were supported to a similar degree, although measurable difficulty occurred in both cases. In other words, the degree of processing difficulty varied as a function of the cumulative support for the re-

quired structure up to disambiguation. Experiment 2 ruled out the unrestricted race account of syntactic ambiguity resolution, which predicted that the dispreferred CC analysis would sometimes be adopted if the RC and the CC alternatives were approximately equally supported, because no processing difficulty was observed in the Weak RC-bias Ambiguous Condition. In addition, the study showed that a semantic plausibility constraint resulted in parsing preferences for a particular structure, even if the constraint occurred late during the ambiguous region, which provided evidence for the multi-constraint based theories.

The data in the dissertation could be best accounted for by a constraint-based comprehension theory. The activation levels of structural alternatives are determined by the interaction between multiple constraints during the ambiguous region of a sentence. As a constraint-based parallel parsing system, the surprisal theory (Hale, 2001) assumes that the parser allocates different amounts of resources to structural alternatives of a syntactic ambiguity based on the input constraints, and difficulty arises when the ultimately required analysis turns out to receive inefficient allocation. As shown in Experiments 1 and 2, the ultimately correct CC structure was assigned fewer resources when both the syntactic and the semantic constraints favored the RC structure than when only the syntactic information supported the RC. Thus, greater processing difficulty occurred at the disambiguation in the former case.

In other words, processing difficulty was caused by resource reallocation during disambiguation rather than by competition between equally-activated structures during the ambiguous region. Experiments 1 and 2 thus ruled out the constraint-based competition accounts of sentence comprehension that have considered unresolved ambiguity as the

primary source of processing difficulty (e.g. Spivey & Tanenhaus, 1998; McRae et al., 1998). Moreover, the data were inconsistent with a parsing system that quickly selects the most probable structure on a word-by-word basis even if multiple alternatives are activated initially (e.g. Traxler et al., 1998; Van Gompel et al., 2001). Unlike the unrestricted race account, the surprisal theory (Hale, 2001) assumes that the parser is sensitive to the different activation level of simultaneously maintained parses during the ambiguous region of a sentence. The surprisal theory thus predicts processing difficulty whenever the new material requires a dispreferred structure that has received much less activation relative to the initially preferred alternative. In other words, processing cost is determined by the relative activation between structural analyses rather than merely by the amount of support for a particular alternative.

The surprisal theory (Hale, 2001) can also explain the length effect in Hsieh et al. (2009), such that resource reallocation would be more costly as the initially preferred RC structure received more support and thus more resource allocation over time relative to the ultimately required CC alternative. On the other hand, although a serial parsing system could accommodate the findings in Experiment 1 if the parser is sensitive to semantic constraints during the ambiguous region, it cannot account for Hsieh et al.'s observation that structural revision from the RC to the CC structure elicited no difficulty when the disambiguation immediately followed the local ambiguity (i.e. the function word *de*) because a serial model assumes that non-local structural revision must be associated with some processing cost.

In addition to the semantic constraint, Experiments 3 and 4 revealed that syntactic priming could function as a constraint during syntactic processing. Experiment 3 investi-

gated how prior experience with the RC structure influences the processing of the syntactic ambiguity, *Verb NP₁ de NP₂*, using a self-paced reading paradigm. The goal of the experiment was to test whether syntactic priming in comprehension involves abstract syntactic representations or entirely depends on specific lexical items. The results showed that structural revision from the RC to the CC analysis was more difficult when the target sentences were preceded by RC primes, even if the primes and the targets did not share any content words. In other words, syntactic priming might facilitate the activation level of the preferred RC structure, making the ultimately required CC alternative even less accessible at disambiguation. Given the lack of content word repetition in the experiment, the priming was unlikely to be entirely lexically driven, although the effect could be enhanced by function word priming. The finding suggested that syntactic priming in comprehension must involve the activation of abstract syntactic configurations.

Furthermore, Experiment 4 explored how syntactic ambiguity resolution in one language can be affected by prior experience with the other language. In particular, the experiment addressed the intriguing question regarding whether two structures that differ in word order across languages share a single representation in the bilingual mind. The findings showed that word order difference did not eliminate the priming effect from English RC structure (head-initial) to Chinese RC structure (head-final). Prior exposure to the RC structure in English increased the activation of the corresponding structure in Chinese as reflected in the elevated reading times at disambiguation in the subsequent target sentences, where the RC had to be revised as a CC structure. The cross-linguistic priming effect provided evidence for an integrated representation of Chinese and English RC structures, which share a specific mapping between syntactic constituents and thematic

roles. In addition, a syntactic structure can persist across languages in the absence of word order repetition, suggesting that the serial information might be represented independently.

Overall, the dissertation contributes to a better understanding of the mechanisms underlying syntactic ambiguity resolution. First of all, syntactic processing is at least somewhat parallel: multiple syntactic analyses can be maintained in memory during the ambiguous region of a sentence, with the more supported structure ranked higher. Processing difficulty associated with structural revision increases as the initially preferred analysis receives higher activations from the available constraints relative to the ultimately required alternative. Secondly, the results support a constraint-based interactive comprehension process, during which all available information is utilized on a word-by-word basis to determine the ranking of structural alternatives of an ambiguous sentence, although the parser probably does not commit to a single analysis until the disambiguating point. In particular, the activation strength of a particular structure is determined by the interaction among multiple constraints rather than by a single cue like an experience-based structural constraint resulting from syntactic priming. Third, syntactic priming can exist without content word or word order repetition across sentences, although the effect could be boosted by lexical or word order priming. In other words, structural persistence must involve the representation of a syntactic configuration unbound to specific lexical items or languages.

However, while syntactic priming is likely to involve activation at the syntactic level, it is unclear whether the source of the priming effect is purely syntactic. The prime and target sentences in Experiment 3 and 4 share the function word *de* (i.e. the RC marker) or

its translation equivalent as well as thematic roles. In other words, structural persistence might in fact reflect both implicit learning of the primed syntactic structure (Bock & Griffin, 2000) and residual activation for lexical items in the prime sentences and the associated syntactic structure (Pickering & Branigan, 1998). In fact, Chang (2002) proposed a dual-path model of sentence production with the attempt to account for the acquisition and use of syntax. The architecture comprised a sequencing system and a meaning system. The sequencing system can learn to create dynamic structural frames out of word sequences, and the syntactic abstractions are independent of specific meanings. The meaning system contains the semantic message, such as lexical and thematic role information. Thus, the model can learn different types of information in each pathway, which then combine to causes changes in processing. From this viewpoint, syntactic priming is a consequent of the combination of syntactic and lexical/semantic effects.

In future work, it would be valuable to further explore whether and how syntactic information is employed similarly or differently in language comprehension than in production. Presumably, comprehension and production processes can influence each other during language processing and acquisition. It has been shown that representations developed during comprehension can facilitate subsequent production and that production preferences can predict comprehension difficulty. Bock et al. (2007) demonstrated that the effect of comprehension-to-production priming was as robust as that of production-to-production priming. In particular, just listening to the prime sentences significantly increased the production of passive and prepositional dative structures subsequently. Meanwhile, Gennari and MacDonald (2009) showed that comprehension difficulty in the object relative clauses was correlated with the production preferences of the verbs. For

example, the sentence *The director that the movie pleased had received a prize* elicited more comprehension difficulty at the critical region *had received* compared to the sentence *The movie that the director watched had received a prize*. The authors argued that the first sentence was more difficult to comprehend because the theme-experiencer verb, *please*, is more likely to be produced in passives, as shown in the corpus analyses, compared to the agent-theme verb, *watch*. In other words, comprehension difficulty in object relative clauses can in part be predicted by the likelihood of the verbs occurring in passive structures in production.

In addition to the interaction between language comprehension and production processes, it is necessary to better understand how syntactic and lexical information interact in bilingual processing, including how structural persistence can be affected by translation-equivalent words across languages. Using dative structure, Schoonbaert et al. (2007) examined syntactic priming within Dutch (L1) and English (L2) as well as priming between Dutch and English. Interestingly, the authors found that although both verb repetition (within both L1 and L2) and translation-equivalent verbs (from Dutch L1 and English L2) could enhance the magnitude of the syntactic priming effect, lexical boost was weaker in cross-linguistic priming compared to within-language priming. The understanding of the role of lexical representation in syntactic priming will help to answer the question of how syntactic knowledge is shared across languages.

In general, the empirical results in the dissertation provide evidence for an expectation-based paradigm of sentence comprehension (Levy, 2008). Sentence comprehension could be understood as an incremental probabilistic decision making process with predictions about upcoming linguistic material on the basis of previous and current input. Ac-

cording to the surprisal theory (Hale, 2001), the difficulty of upcoming material is proportional to its surprisal, such that highly predictable material causes lower surprisal than does less predictable material. The predictability of the upcoming material to be read or heard is calculated based on the weighed sum of the activations of all available constraints as a sentence unfolds, including the experience-based constraint at the structural level. Although few, if any, constraint-based parsing model has explicitly incorporated the experience-based sources, the parser does draw upon both lexical and non-lexical information during sentence comprehension in order to determine the most probable interpretation incrementally.

Appendix A. Experimental Stimuli of Experiment 1

Within both the Strong and the Weak sets, the words that distinguish the ambiguous and unambiguous conditions are given in parentheses, with the ambiguous condition first. The percentage in parentheses represents the percentage of RC completions for each item.

<u>Strong</u>

1.

虐待(小孩/善良)的保姆之後，那對夫妻被鄰居檢舉。(5.90)

nuedai (xiaohai/shanliang) de baomu zhihou, nadui fuqi bei linju jianju.

abuse (child/kind) (POSS/ATT) nanny after, the couple PASSIVE neighbor accuse

After abusing the (child's/kind) nanny, the couple were accused by the neighbors.

2.

探視(病人/無助)的醫生之後，那個院長坐車離開醫院。(6.35)

tanshi (bingren/wuzhu) de yisheng zhihou, nage yuanzhang zuoche likai yiyuan.

visit (patient/hopeless) (POSS/ATT) doctor after, the director by car leave hospital

After visiting the (patient's/hopeless) doctor, the director left the hospital by car.

3.

拜訪(教授/優秀)的學生之前，那個助教買了禮物。(5.82)

baifang (jiaoshou/youxiu) de xuesheng zhiqian, nage zhujiao mai le liwu.

visit (professor/outstanding) (POSS/ATT) student before, the teaching assistant buy

PERF gift

Before visiting the (professor's/outstanding) student, the teaching assistant bought a gift.

4.

協助(醫生/年輕)的護士之後，那位助手感到很疲倦。(6.08)

xiezhu (yisheng/nianqing) de hushi zhihou, nawei zhushou gandao hen pijuan.

assist (doctor/young) (POSS/ATT) nurse after, the assistant feel very tired

After assisting the (doctor's/young) nurse, the assistant felt very tired.

5.

指導(演員/業餘)的導演之後，那位編劇出席了記者會。(6.54)

zhidao (yanyuan/yeyu) de daoyan zhihou, nawei bianju chuxi le jizhehui.

instruct (actor/amateur) (POSS/ATT) director after, the playwright attend PERF press
conference

*After instructing the (actors'/amateur) director, the playwright attended a press confe-
rence.*

6.

訓練(士兵/年輕)的將軍之前，那位總司令發表了演說。(6.33)

xunlian (shibing/nianqing) de jiangjun zhiqian, nawei zongsiling fabiao le yanshuo.

train (soldier/young) (POSS/ATT) general before, the commander give PERF speech

Before training the (soldiers'/young) general, the commander gave a speech.

7.

保護(主人/名貴)的獵犬之餘，那個僕人還要做粗活。(6.46)

baohu (zhuren/minggui) de liequan zhiyu, nage puren haiyao zuo cuhuo.

protect (master/precious) (POSS/ATT) hunting dog while, the servant also do labor work

While protecting the (master's/precious) hunting dog, the servant also did housework.

8.

陷害(同事/無辜)的員工之前，那個男人策劃了很久。(6.67)

xianhai (tongshi/wugu) de yuangong zhiqian, nage nanren cehua le henjiu.

set up (colleague/innocent) (POSS/ATT) employee before, the man plan PERF long time

Before setting up the (colleague's/innocent) employee, the man had planned for a long time.

9.

服務(旅客/資深)的導遊之後，那個服務生得到一筆小費。(5.83)

fuwu (luke/zishen) de daoyou zhihou, nage fuwusheng dedao yibi xiaofei.

Serve (tourist/experienced) (POSS/ATT) tour guide after, the waiter receive a tip

After serving the (tourists'/experienced) tour guide, the waiter received a tip.

10.

責罵(學生/盡責)的老師之後，那個校長覺得很後悔。(6.32)

zema (xuesheng/jinze) de laoshi zhihou, nage xiaozhangbei juede hen houhui.

scold (student/responsible) (POSS/ATT) teacher after, the headmaster feel very regretful

After scolding the (students'/responsible) teacher, the headmaster felt very regretful.

11.

服侍(國王/知名)的廚師之後，那個年輕人得到升遷機會。(6.82)

fushi (guowang/zhiming) de chushi zhihou, nage nianqingren dedao shengqian jihui.

serve (king/famous) (POSS/ATT) cook after, the young man get promotion opportunity

After serving the (king's/famous) cook, the young man got an opportunity of promotion.

12.

陪伴(考生/焦慮)的家長之後，那位主任離開了考場。(6.41)

peiban (kaosheng/jiaolu) de jiazhang zhihou, nawei laoshi likai le jiaoshi.

accompany (examinee/anxious) (POSS/ATT) parent after, the teacher leave PERF class-room

After accompanying the (examinee's/anxious) parents, the teacher left the classroom.

13.

服從(主管/資深)的秘書之餘，那位新人也很有野心。(6.22)

fucong (zhuguan/zishen) de mishu zhiyu, nawei xinren ye henyou yexin.

obey (boss/senior) (POSS/ATT) secretary while, the newcomer also have ambition

While obeying the (boss's/senior) secretary, the newcomer also had ambition.

14.

怠慢(客人/年長)的司機之後，那位店員被老闆責罵。(5.88)

daiman (keren/nianzhang) de siji zhihou, nawei dianyuan bei laoban zema.

slight (customer/elder) (POSS/ATT) driver after, the cashier PASSIVE boss blame

After slighting the (customer's/elder) driver, the cashier was blamed by the boss.

15.

稱讚(球員/專業)的教練之後，那位球迷還要求簽名。(5.35)

chengzan (qiuyuan/zhuanye) de jiaolian zhihou, nawei qiumi hai yaoqiu qianming.

praise (player/professional) (POSS/ATT) coach after, the fan also ask for signature

After praising the (player's/professional) coach, the fan also asked for signature.

16.

想念(孩子/慈祥)的母親之餘，那個男人決定提早回家。(6.11)

xiangnian (haizi/cixiang) de muqin zhiyu, nage nanren jueding tizao huijia.

miss (child/kind) (POSS/ATT) mother while, the man decide earlier go home

While missing the (child's/kind) mother, the man decided to go home earlier.

17.

尊敬(老師/上進)的孩子之餘，那個學生更加努力學習。(6.90)

zunjing (laoshi/shangjin) de haizi zhiyu, nage xuesheng gengjia nuli xuexi.

respect (teacher/diligent) (POSS/ATT) child while, the student even more hard study

While respecting the (teacher's/diligent) child, the student studied even harder.

18.

欺騙(住戶/富有)的房東之後，那個管理員被警察逮捕。(5.81)

qipian (zhuhu/fuyou) de fangdong zhihou, nage guanliyuan bei jingcha daibu.

deceive (resident/rich) (POSS/ATT) landlord after, the manager PASSIVE police arrest

After deceiving the (resident's/rich) landlord, the manager was arrested by the police.

19.

照顧(老人/貧窮)的看護之餘，那個雇主還提供三餐。(6.78)

zhaogu (laoren/pinqiong) de kanhu zhiyu, nage guzhu hai tigong sancan.

take care of (old man/poor) (POSS/ATT) nurse while, the employer also provide meal

While taking care of the (old man's/poor) nurse, the employer also provided meals.

20.

測驗(學徒/年輕)的師傅之前，那位主考官說明了規則。(6.10)

ceyan (xuetu/nianqing) de shifu zhiqian, nawei zhukaoguan shuoming le guize.

test (apprentice/young) (POSS/ATT) master worker before, the judge explain PERF rule

Before testing the (apprentice's/young) master worker, the judge explained the rules.

Weak

1.

安慰(病人/悲傷)的家屬之後，那位護士離開了病房。(4.00)

anwei (bingren/beishang) de jiashu zhihou, nawei hushi likai le bingfang.

comfort (patient/sad) (POSS/ATT) family member after, the nurse leave PERF ward

After comforting the patient's/sad family member, the nurse left the ward.

2.

恐嚇(被告/正直)的律師之後，那位法官被停職一年。(4.21)

konghe (beigao/zhengzhi) de lushi zhihou, nawei faguan bei tingzhi yinian.

threaten (defendant/upright) (POSS/ATT) lawyer after, the judge PASSIVE suspend a year

After threatening the (defendant's/upright) lawyer, the judge was suspended for a year.

3.

看見(老闆/忙碌)的秘書之前，那個職員正準備開會。(4.00)

kanjian (laoban/manglu) de mishu zhiqian, nage zhiyuan zheng zhunbei kaihui.

see (boss/busy) (POSS/ATT) secretary before, the employee PROG prepare meeting

Before seeing the (boss's/busy) secretary, the employee was preparing for a meeting.

4.

嘲笑(工人/天真)的小孩之後，那個學生覺得很後悔。(4.29)

chaoxiao (gongren/tianzhen) de xiaohai zhihou, nage xuesheng juede hen houhui.

mock (worker/naive) (POSS/ATT) child after, the student feel very regretful

After mocking the (worker's/ naive) child, the student felt very regretful.

5.

連絡(災民/焦急)的親人之後，那位消防隊員繼續營救傷者。(4.00)

lianluo (zaimin/jiaoji) de qinren zhihou, nawei xiaofangduiyuan jixu yingjiu shangzhe.

contact (victim/anxious) (POSS/ATT) relative after, the firefighter continue relieve the injured

After contacting the (victim's/anxious) relative, the firefighter continued to relieve the injured.

6.

欺騙(朋友/仁慈)的老闆之後，那個女孩感到很不安。(4.00)

qipian (pengyou/renci) de laoban zhihou, nage nuhai gandao hen buan.

deceive (friend/kind) (POSS/ATT) boss after, the girl feel very uneasy

After deceiving the (friend's/kind) boss, the girl felt very uneasy.

7.

等待(小孩/遲到)的老師之餘，那個家長參觀了校園。(4.17)

dengdai (xiaohai/chidao) de laoshi zhiyu, nage jiazhang canguan le xiaoyuan.

wait (child/late) (POSS/ATT) teacher while, the parent visit PERF campus

While waiting for the (child's/late) teacher, the parent visited the campus.

8.

毀謗(總裁/勤奮)的助理之後，那位員工立刻被解僱。(4.25)

huibang zongcai/qinfen de zhuli zhihou, nawei yuangong like bei jiegu.

defame (CEO/diligent) (POSS/ATT) assistant after, the employee immediately PASSIVE fire

After defaming the (CEO's/diligent) assistant, the employee was fired immediately.

9.

幫助(朋友/貧困)的學生之後，那位老師感到很開心。(4.21)

bangzhu (pengyou/pinkun) de xuesheng zhihou, nawei laoshi gandao hen kaixin.

help (friend/poor) (POSS/ATT) student after, the teacher fell very happy

After helping the (friend's/poor) student, the teacher felt very happy.

10.

侮辱(球員/熱情)的球迷之後，那個教練感到很抱歉。(4.04)

wuru (qiuyuan/reqing) de qiumi zhihou, nage jiaolian gandao hen baoqian.

insult (player/enthusiastic) (POSS/ATT) fan after, the coach feel very sorry

After insulting the (player's/enthusiastic) fan, the coach felt very sorry.

11.

尋找(老人/失蹤)的親人之前，那個男人向警方求助。(4.00)

xunzhao (laoren/shizong) de qinren zhiqian, nage nanren sichu dating xiaoxi.

look for (old man/missing) (POSS/ATT) relative before, the man to the police ask for help

Before looking for the (old man's/missing) relative, the man asked the police for help.

12.

傷害(鄰居/可愛)的小狗之後，那個男孩感到很害怕。(4.21)

shanghai (linju/keai) de xiaogou zhihou, nage nanhai gandao hen haipa.

hurt (neighbor/cute) (POSS/ATT) dog after, the boy feel very afraid

After hurting the (neighbor's/cute) dog, the boy felt very afraid.

13.

安撫(病童/緊張)的父母之後，那位醫生走進辦公室休息。(4.38)

anfu (bingtong/jinzhang) de fumu zhihou, nawei yisheng zoujin bangongshi xiuxi.

pacify (sick child/nervous) (POSS/ATT) parents after, the doctor enter office rest

After pacifying the (sick child's/nervous) parents, the doctor entered the office to rest.

14.

賄賂(總統/貪婪)的保鑣之後，那位記者獲得不少內幕。(4.00)

huilu (zongtong/tanlan) de baobiao zhihou, nawei jizhe zhidao bushao neimu.

bribe (President/greedy) (POSS/ATT) body guard after, the reporter know many secret

After bribing the (President's/greedy) body guard, the reporter knew many secrets.

15.

關心(老師/孤單)的小孩之後，那個學生走路去學校。(4.08)

guanxin (laoshi/gudan) de xiaohai zhihou, nage xuesheng zoulu qu xuexiao.

care (teacher/lonely) (POSS/ATT) child after, the student walk to school

After caring about the (teacher's/lonely) child, the student walked to school.

16.

拜訪(母親/熟識)的醫生之前，那個女人打了電話。(4.00)

baifang (muqin/shoushi) de yisheng zhiqian, nage nuren da le dianhua.

visit (mother/familiar) (POSS/ATT) doctor before, the woman make PERF phone call

Before visiting the (mother's/familiar) doctor, the woman made a phone call.

17.

認識(名人/知名)的設計師之後，那個少女覺得很興奮。(4.04)

renshi (mingren/zhiming) de shejishi zhihou, nage shaonu juede hen xingfen.

know (celebrity/famous) (POSS/ATT) stylist after, the teenager feel very excited

After knowing the (celebrity's/famous) stylist, the teenager felt very excited.

18.

批評(選手/權威)的教練之前，那個記者沒有蒐集資料。(4.13)

piping (xuanshou/quanwei) de jiaolian zhiqian, nage jizhe meiyou souji ziliao.

criticize (contestant/authoritative) (POSS/ATT) coach before, the reporter does not collect information

Before criticizing the (contestant's/authoritative) coach, the reporter did not collect information.

19.

抱怨(部隊/懶惰)的新兵之餘，那個指揮官決定加強訓練。(4.25)

baoyuan (budui/landuo) de xinbing zhiyu, nage zhihuiguan jueding jiaqiang xunlian.

complain (army/lazy) (POSS/ATT) recruit while, the commander decide strengthen training

While complaining about the (army's/lazy) recruits, the commander decided to strengthen the training.

20.

出賣(親戚/真誠)的朋友之後，那個女人堅持不認錯。(4.00)

chumai (qinqi/zhencheng) de pengyou zhihou, nage nuren jianchi bu rencuo.

betray (relative/sincere) (POSS/ATT) friend after, the woman insist not admit

After betraying the (relative's/sincere) friend, the woman insisted not to admit.

Appendix B. Experimental Stimuli of Experiment 2

Within both the Strong and the Weak sets, the words that distinguish the ambiguous and unambiguous conditions are given in parentheses, with the ambiguous condition first.

<u>Strong</u>

1.

(常常/那個)虐待小孩的保姆缺乏愛心。

(changchang/nage) nuedai xiaohai de baomu quefa aixin.

(often/the) abuse child RC nanny lack sympathy

(A nanny who often abuses children/The nanny who abuses children) lacks sympathy.

2.

(天天/那個)探視病人的醫生工作很負責。

(tiantian/nage) tanshi bingren de yisheng gongzuo henfuze.

(every day/the) visit patient RC doctor work very responsibly

(A doctor who visits patients every day/The doctor who visits patients) works very responsibly.

3.

(常常/那個)拜訪教授的學生懂得感恩。

(henshao/nage) baifang jiaoshou de xuesheng dongde ganen.

(changchang/the) visit professor RC student know be thankful

(A student who often visits professors/The student who visits professors) knows to be thankful.

4.

(常常/那個)協助醫生的護士做事很熟練。

(changchang/nage) xiezhu yisheng de hushi zuoshi henshoulian.

(often/the) assist doctor RC nurse act very proficiently

(A nurse who often assists doctors/The nurse who assists doctors) acts very proficiently.

5.

(每天/那個)指導演員的導演工作很辛苦。

(meitian/nage) zhidao yanyuan de daoyan gongzuo henxinku.

(every day/the) instruct actor RC director work very hard

(A director who instructs actors every day/The director who instructs actors) works very hard.

6.

(每天/那個)訓練士兵的將軍帶兵很負責。

(meitian/nage) xunlian shibing de jiangjun daibing henfuze.

(every day/the) train soldier RC general lead very responsibly

(A general who trains soldiers every day/The general who trains soldiers) leads very responsibly.

7.

(天天/那隻)保護主人的獵犬表現很忠誠。

(tiantian/nazhi) baohu zhuren de liequan biaoxian henzhongcheng.

(every day/The) protect master RC hunting dog behave very loyally

(A hunting dog that protects the master every day/The hunting dog that protects the master) behaves very loyally.

8.

(常常/那個)陷害同事的員工不值得信任。

(changchang/nage) xianhai tongshi de yuangong buzhide xinren.

(often/the) set up colleague RC employee not deserve trust

(An employee who often sets up colleagues/The employee who sets up colleagues) does not deserve trust.

9.

(常常/那個)服務旅客的導遊很有經驗。

(changchang/nage) fuwu luke de daoyou henyou jingyan.

(often/the) serve tourist RC tour guide have experience

(A tour guide who often serves tourists/The tour guide who serves tourists) has experience.

10.

(常常/那個)責罵學生的老師缺乏耐心。

(changchang/nage) zema xuesheng de laoshi quefa naixin.

(often/the) blame student RC teacher lack patience

(A teacher who often blames students/The teacher who blames students) lacks patience.

11.

(天天/那個)服侍國王的廚師工作很辛苦。

(tiantian/nage) fushi guowang de chushi gongzuo henxinku.

(every day/the) serve king RC cook work very hard

(A cook who serves a king every day/The cook who serves a king) works hard.

12.

(一直/那些)陪伴考生的家長很有耐心。

(yizhi/naxie) peiban kaosheng de jiazhang henyou naixin.

(always/those) accompany examinee RC parent have patience

(Parents who always accompany examinees/The parents who accompany examinees) have patience.

13.

(總是/那個)服從主管的祕書值得信任。

(zongshi/nage) fucong zhuguan de mishu zhide xinren.

(always/the) obey boss RC secretary deserve trust

(A secretary who always obeys the boss/The secretary who obeys the boss) deserves trust.

14.

(常常/那個)怠慢客人的司機不值得推薦。

(changchang/nage) daiman keren de siji buzhide tuijian.

(often/the) slight customer RC driver not deserve recommendation

(A driver who often slights customers/The driver who slights customers) does not deserve recommendation.

15.

(常常/那個)稱讚球員的教練受到愛戴。

(changchang/nage) chengzan qiuyuan de jiaolian shoudao aidai.

(often/the) praise player RC coach win respect

(A coach who often praises players/The coach who praises players) wins respect.

16.

(常常/那個)想念孩子的母親值得同情。

(changchang/nage) xiangnian haizi de muqin zhide tongqing.

(often/the) miss child RC mother deserve sympathy

(A mother who often misses the child/The mother who misses the child) deserves sympathy.

17.

(總是/那個)尊敬老師的孩子值得肯定。

(zongshi/nage) zunjing laoshi de haizi zhide kending

(always/the) respect teacher RC child deserve recognition

(A child who always respects teachers/The child who respects teachers) deserves recognition.

18.

(常常/那個)欺騙住戶的房東不值得信任。

(changchang/nage) qipian zhuhu de fangdong buzhide xinren.

(often/the) deceive resident RC landlord not deserve trust

(A landlord who often deceives residents/The landlord who deceives residents) does not deserve trust.

19.

(每天/那個)照顧老人的看護工作很辛苦。

(meitian/nage) zhaogu laoren de kanhu gongzuo henxinku.

(every day/the) take care of old people RC nurse work very hard

(A nurse who takes care of old people every day/The nurse who takes care of old people)

works very hard.

20.

(常常/那個)測驗學徒的師傅要求很高。

(changchang/nage) ceyan xuetu de shifu yaoqiu hengao.

(often/the) test apprentice RC master worker demand a lot

(A master worker who often tests apprentices/The master worker who tests apprentices)

demands a lot.

Weak

1.

(每天/那個)安慰病人的家屬具有同理心。

(meitian/nage) anwei bingren de jiashu juyou tonglixin.

(every day/the) comfort patient RC family member have empathy

(A family member who comforts patients every day/The family member who comforts pa-

tients) has empathy.

2.

(常常/那個)恐嚇被告的律師缺乏道德。

(changchang /nage) konghe beigao de lushi quefa daode.

(often/the) threaten defendant RC lawyer lack moral

(A lawyer who often threatens defendants/The lawyer who threatens defendants) lacks morals.

3.

(每天/那個)看見老闆的秘書不敢偷懶。

(meitian/nage) kanjian laoban de mishu bugan toulan.

(every day/the) see boss RC secretary not dare be lazy

(A secretary who sees the boss every day/The secretary who sees the boss) does not dare to be lazy.

4.

(常常/那個)嘲笑工人的小孩不懂禮貌。

(changchang/nage) chaoxiao gongren de xiaohai budong limao.

(often/the) mock worker RC child not know decency

(A child who often mocks workers/The child who mocks workers) does not know decency.

5.

(每天/那些)聯絡災民的親人盼望好消息。

(meitain/naxie) lianluo zaimin de qinren panwang haoxiaoxi.

(every day/those) contact victim RC relative long for good news

(Relatives who contact victims every day/The relatives who contact victims) long for good news.

6.

(常常/那個)欺騙朋友的老闆不值得信任。

(changchang/nage) qipian pengyou de laoban buzhide xinren.

(often/the) deceive friend RC boss not deserve trust

(A boss who often deceives friends/The boss who deceives friends) does not deserve trust.

7.

(每天/那個)等待小孩的老師很有耐心。

(meitian/nage) dengdai xiaohai de laoshi henyou naixin.

(every day/the) wait child RC teacher have patience

(A teacher who waits for children every day/The teacher who waits for children) has patience.

8.

(常常/那個)毀謗總裁的助理不值得信任。

(changchang/nage) huibang zongcai de zhuli buzhide xinren.

(often/the) defame CEO RC assistant not deserve trust

(An assistant who often defames the CEO/The assistant who defames the CEO) does not deserve trust.

9.

(常常/那個)幫助朋友的學生值得獎勵。

(changchang/nage) bangzhu pengyou de xuesheng zhide jiangli.

(often/the) help friend RC student deserve encouragement

(A student who often helps friends/The student who helps friends) deserves encouragement.

10.

(常常/那個)侮辱球員的球迷缺乏尊重。

(changchang/nage) wuru qiuyuan de qiumi quefa zunzhong.

(often/the) insult player RC fan lack respect

(A fan who often insults players/The fan who insults players) lacks respect.

11.

(每天/那些)尋找老人的親人忍受痛苦。

(meitain/naxie) xunzhao laoren de qinren renshou tongku.

(every day/those) look for old man RC relative endure suffering

(A relative who looks for an old man every day/The relative who looks for an old man)

endures suffering.

12.

(常常/那隻)傷害鄰居的小狗造成威脅。

(changchang/nazhi) shanghai linju de xiaogou zaocheng weixie.

(often/the) hurt neighbor RC dog cause threat

(A dog that often hurts neighbors/The dog that hurts neighbors) causes threat.

13.

(每天/那對)安撫病童的父母付出很多。

(meitian/nadui) anfu bingtong de fumu fuchu henduo.

(every day/the) pacify sick child RC parent devote a lot

(Parents who pacify a sick child every day/The parents who pacify a sick child) devote a

lot.

14.

(常常/那個)賄賂總統的保鑣缺乏紀律。

(changchang/nage) huilu zongtong de baobiao quefa jilu.

(often/the) bribe President RC body guard lack discipline

(A body guard who often bribes the President/The body guard who bribes the President)

lacks discipline.

15.

(常常/那個)關心老師的小孩表現成熟。

(changchang/nage) guanxin laoshi de xiaohai biaoxian chengshou.

(often/the) care about teacher RC child act maturely

(A child who often cares about teachers/The child who cares about teachers) acts ma-

turely.

16.

(常常/那個)拜訪母親的醫生很有孝心。

(changchang/nage) baifang muqin de yisheng henyou xiaoxin.

(often/the) visit mother RC doctor have filial piety

(A doctor who often visits the mother/The doctor who visits the mother) has filial piety.

17.

(常常/那個)認識名人的設計師擅於交際。

(changchang/nage) renshi mingren de shejishi shanyu jiaoji.

(often/the) know celebrity RC stylist be good at networking

(A stylist who often knows celebrities/The stylist who knows celebrities) is good at networking.

18.

(常常/那個)批評選手的教練缺乏智慧。

(changchang/nage) piping xuanshou de jiaolian quefa zhihui.

(often/the) criticize contestant RC coach lack wisdom

(A coach who often criticizes contestants/The coach who criticizes contestants) lacks wisdom.

19.

(常常/那個)抱怨部隊的新兵缺乏耐力。

(changchang/nage) baoyuan budui de xinbing quefa naili.

(often/the) complain army RC recruit lack endurance

(A recruit who often complains about the army/The recruit who complains about the army) lacks endurance.

20.

(常常/那個)出賣親戚的朋友缺乏誠信。

(changchang/nage) chumai qinqi de pengyou quefa chengxin.

(often/the) betray relative RC friend lack honesty

(A friend who often betrays relatives/The friend who betrays relatives) lacks honesty.

Appendix C. Experimental Stimuli of Experiments 3 and 4

The Prime and No Prime conditions in both Experiments 3 and 4 used the same target sentences. The grammaticality ratings of the target sentences were given in parentheses, with ratings of the Prime condition first. The ratings of Experiment 3 are provided in the first parentheses and those of Experiment 4 in the second parentheses.

1.

安慰病人的家屬之後，那位護士離開了病房。(4.0; 4.7) (3.9; 4.2)

anwei bingren de jiashu zhihou, nawei hushi likai le bingfang.

comfort patient POSS family member after, the nurse leave PERF ward

After comforting the patient's family member, the nurse left the ward.

2.

恐嚇被告的律師之後，那位法官被停職一年。(4.9; 4.4) (4.4; 4.8)

konghe beigao de lushi zhihou, nawei faguan bei tingzhi yinian.

threaten defendant POSS lawyer after, the judge PASSIVE suspend a year

After threatening the defendant's lawyer, the judge was suspended for a year.

3.

看見老闆的秘書之前，那個職員正準備開會。(3.6; 4.9) (4.1; 4.1)

kanjian laoban de mishu zhiqian, nage zhiyuan zheng zhunbei kaihui.

see boss POSS secretary before, the employee PROG prepare meeting

Before seeing the boss's secretary, the employee was preparing for a meeting.

4.

嘲笑工人的小孩之後，那個學生覺得很後悔。(4.2; 4.6) (4.3; 4.9)

chaoxiao gongren de xiaohai zhihou, nage xuesheng juede hen houhui.

mock worker POSS child after, the student feel very regretful

After mocking the worker's child, the student felt very regretful.

5.

欺騙朋友的老闆之後，那個女孩感到很不安。(4.7 ; 4.4) (5.1 ; 5.4)

qipian pengyou de laoban zhihou, nage nuhai gandao hen buan.

deceive friend POSS boss after, the girl feel very uneasy

After deceiving the friend's boss, the girl felt very uneasy.

6.

等待小孩的老師之餘，那個家長參觀了校園。(4.3; 4.9) (3.4; 4.0)

dengdai xiaohai de laoshi zhiyu, nage jiazhang canguan le xiaoyuan.

wait child POSS teacher while, the parent visit PERF campus

While waiting for the child's teacher, the parent visited the campus.

7.

毀謗總裁的助理之後，那位員工立刻被解僱。(4.5; 5.1) (5.0; 5.7)

huibang zongcai de zhuli zhihou, nawei yuangong like bei jiegu.

defame CEO POSS assistant after, the employee immediately PASSIVE fire

After defaming the CEO's assistant, the employee was fired immediately.

8.

幫助朋友的學生之後，那位老師感到很開心。(4.9; 5.6) (4.6; 5.0)

bangzhu pengyou de xuesheng zhihou, nawei laoshi gandao hen kaixin.

help friend POSS student after, the teacher fell very happy

After helping the friend's student, the teacher felt very happy.

9.

侮辱球員的球迷之後，那個教練感到很抱歉。 (4.7; 5.0) (4.7; 4.3)

wuru qiuyuan de qiumi zhihou, nage jiaolian gandao hen baoqian.

insult player POSS fan after, the coach feel very sorry

After insulting the player's fan, the coach felt very sorry.

10.

安撫病童的父母之後，那位醫生走進辦公室休息。 (5.0; 5.6) (4.7; 5.1)

anfu bingtong de fumu zhihou, nawei yisheng zoujin bangongshi xiuxi.

pacify sick child POSS parents after, the doctor enter office rest

After pacifying the sick child's parents, the doctor entered the office to rest.

11.

關心老師的小孩之後，那個學生走路去學校。 (5.1; 4.6) (5.4; 4.9)

guanxin laoshi de xiaohai zhihou, nage xuesheng zoulu qu xuexiao.

care teacher POSS child after, the student walk to school

After caring about the teacher's child, the student walked to school.

12.

拜訪母親的醫生之前，那個女人打了電話。 (4.9; 5.8) (5.1; 5.7)

baifang muqin de yisheng zhiqian, nage nuren da le dianhua.

visit mother POSS doctor before, the woman make PERF phone call

Before visiting the mother's doctor, the woman made a phone call.

13.

認識名人的設計師之後，那個少女覺得很興奮。(4.8; 4.4) (5.4; 5.2)

renshi mingren de shejishi zhihou, nage shaonu juede hen xingfen.

know celebrity POSS stylist after, the teenager feel very excited

After knowing the celebrity's stylist, the teenager felt very excited.

14.

批評選手的教練之前，那個記者沒有蒐集資料。(5.0; 5.8) (4.8; 5.3)

piping xuanshou de jiaolian zhiqian, nage jizhe meiyou souji ziliao.

criticize contestant POSS coach before, the reporter does not collect information

Before criticizing the contestant's coach, the reporter did not collect information.

15.

抱怨部隊的新兵之餘，那個指揮官決定加強訓練。(3.8; 4.5) (3.6; 4.1)

baoyuan budui de xinbing zhiyu, nage zhihuiguan jueding jiaqiang xunlian.

complain army POSS recruit while, the commander decide strengthen training

While complaining about the army's recruits, the commander decided to strengthen the training.

16.

出賣親戚的朋友之後，那個女人堅持不認錯。(5.1; 5.0) (5.3; 5.3)

chumai qinqi de pengyou zhihou, nage nuren jianchi bu rencuo.

betray relative POSS friend after, the woman insist not admit

After betraying the relative's friend, the woman insisted not to admit.

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