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Processing gap-filler dependencies in Chinese: What does it tell us about semantic processing?

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Introduction

A longstanding question in linguistics and cognitive science has been the role that syntax and semantics play in sentence processing (van Gompel & Pickering, 2007). Two competing theories have been proposed to describe a modular and an interactive parser. A syntax-first parser uses only structural information to guide the first-pass (Ferreira & Clifton, 1986). In contrast, an interactive parser uses all sources of information simultaneously to arrive at an analysis for the partial input (MacDonald, Perlmutter, & Seidenberg, 1994). The present study employs a novel approach to investigate this issue. It exploits a situation where for an ambiguous fragment, one analysis presents syntactic advantage (e.g., structural economy) and another analysis presents semantic advantage (e.g., provide an agent for the action mentioned). By examining which analysis is adopted, we will know whether the parser gives priority to economizing the structure or maximizing the interpretation of the partial input to form a complete proposition. To this end, the current study employs gap-filler completion in an ambiguous Chinese construction to investigate the fulfillment of competing syntactic and semantic requirements in sentence comprehension.

Gap-filler dependencies are one type of filler-gap relation, in which the gap is received before the filler. An example of this kind of dependency is the English subject clause (e.g., *e_i Climbing Everest is Mary_i's dream.¹*), whereas a typical filler-gap dependency is the English *wh*-question (e.g., *Who_i did Jose interview e_i yesterday?*). Gap-filler dependencies

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¹ Throughout this paper, a lower case *e* indicates the gap position. By convention, matched subscripts on it and another element in the sentence indicate a referential dependency.

are less commonly studied and thus less well-understood than filler-gap dependencies, yet several studies (e.g. Kahraman, 2010; Kwon, 2008) suggest that gap-filler and filler-gap processing share similarities. First, parsing is incremental: a gap is posited once a gap-site is identified. Incremental parsing in gap-filler processing is applicable to both syntactic dependencies (e.g., gap-filler relation in Turkish relative constructions) and non-syntactic coreferential relations (e.g., gap-filler relation in Korean sentences that contain an adjunct clause). Second, once a gap is identified, the parser will actively search for the filler. Gap-filler completion could be motivated by the need to satisfy an interpretation requirement: a gap is a sentence element that has no semantic content, unless it is associated with a referential element (Ng, 2008; see also Aoshima, Phillips, & Weinberg, 2004 for similar motivation for filler-gap completion).

The present study employed two gated sentence-completion and two self-paced reading experiments to investigate the processing of gap-filler dependencies in Mandarin Chinese. Crucially, we inquired whether structural economy is overridden to provide a filler for an identified gap. The overall goal was to examine the role syntax and semantics play in gap-filler processing and ambiguity resolution.

The ambiguous construction relevant to the present study is illustrated in (1). It has the surface word order of *Verb Noun de Noun* ($V+NI+de+N2$) and contains a subject gap. The particle *de*, an adnominal marker, indicates the preceding constituent is a noun modifier. The $V+NI+de+N2$ string is highly ambiguous; it can be a main clause, subject clause, relative clause, and various other less common analyses. This paper only discusses the three most preferred analyses for the construction, as revealed by the results of Experiment 1.

(1)

<i>e</i>	等待	客人	的	朋友
<i>e</i>	wait	guest	DE	friend
Main Clause: “(Someone) waited for the guest’s friend.”				
Subject Clause: “Waiting for the guest’s friend...”				
Relative Clause: “The friend who waited for the guest...”				

Chinese is a S(subject)-V(erb)-O(bject) and *pro*-drop language. It allows the subject to remain phonological null as long as its reference can be recovered from the context. The $V+NI+de+N2$ string in (1) can therefore be a main clause (MC) where the subject gap refers to a discourse referent. It can also be a subject clause (SC) where the subject gap can be interpreted generically or contextually (e.g., *e* *Waiting for the guest’s friend is necessary.*), or can assume a coreferential reading with a noun in the main clause (e.g., *e_i Waiting for the guest’s friend annoyed Sue_i.*). Finiteness is generally not marked in Chinese verbs (Hu, Pan, & Xu, 2001); hence the subject clause can be finite or non-finite. On the other hand, Chinese noun phrases (NPs) are strictly head-final, such that a relative clause and any other noun modifiers precede the head noun that they modify. Thus, the $V+NI+de+N2$ string in (1) can contain a relative clause (RC) in which the subject gap is coindexed with the head noun *friend*. Figure 1 illustrates the three structures. Note that both MC and SC structures are right-branching whereas the RC structure is left-branching.² For these analyses, structural ambiguity interacts with gap interpretation ambiguity, creating an ideal scenario to test the

fulfillment of competing syntactic and semantic requirements in real-time sentence processing.

The critical questions for the present study are what analysis the parser initially prefers for strings like (1) and whether this preference changes to facilitate gap-filler processing. Ng and Fodor (2011) showed in a sentence completion study that for a fragment that contained a null subject and a verb, main and subject clause analyses (83%) were significantly preferred over a RC analysis (4%). There could be several reasons for why the main and subject clauses (collectively called the right-branching structure hereafter) are initially favored over the RC (a left-branching structure) for strings like (1). The most obvious one seems to be structural economy. The structural ambiguity begins at the beginning of the string, when the verb is received. As shown in Figure 1, at the verb *waited*, the RC structure requires building an additional NP and S' node, compared to the main and subject clause.

However, Hsieh, Boland, Zhang, and Yan (2009) maintained that the RC was initially preferred, based on the results of their written sentence completion study that showed a strong RC preference (95%) for the fragment *V+N+de*. There were, nevertheless, problems with this interpretation of their results. First, there was no evidence that the RC preference started from the beginning of the fragment. In addition, the fragment used in their study could inadvertently bias in favor of the RC analysis. In sentence completion studies, a pause is usually inserted between reading and continuing a fragment. This pause likely encourages a complete constituent reading for that fragment. The string *V+N+de* would constitute a complete clause if a RC analysis is adopted, but would be an incomplete constituent if a main or subject clause analysis is adopted (because the object noun is missing). If the string *V+N1+de+N2* is read continuously as in natural reading, such a bias would not occur.

For the *V+N1+de+N2* string as a whole, there are corpus and experimental studies that support both a right-branching and a RC preference. Results of the corpus study by Feng and Xu (2002) indicated that the right-branching structure was more preferred: almost 3 times more right-branching than left-branching analyses. However, the corpus study by Zhang, Zhang, and Shu (2000) showed that for the same word string, 70% were left-branching. In addition, results of their self-paced word-by-word reading study also supported the RC preference. In the reading study, three types of sentences were created by varying the lexical composition in *V+N1+de+N2*: RC-biased, right-branching-biased, and balanced between the two analyses. For the balanced type of sentences, longer reading times were observed at *N2+I* (i.e., the word immediately following *N2*) for the ambiguous sentence, compared to its unambiguous counterpart, *only* when the construction was disambiguated as a right-branching structure, but not when it was disambiguated as a RC structure. This result indicates that in the absence of lexical bias, the RC can be more preferred than the right-branching parse at the end of *V+N1+de+N2*.

² The labels right-branching and left-branching used here represent the general branching direction of a structure. As shown in Figure 1, there is mixed-branching in almost all structures. This is mainly due to the opposite branching direction of a clause and a NP in Chinese. If a clause contains a NP, the clause is right-branching but the NP is left-branching. If a NP contains a clause, the NP is left-branching but the clause is right-branching.

The current study investigates the early preference and a possible later structural shift for $V + N1 + de + N2$. If the initial preference is a right-branching structure, as Ng and Fodor (2011) argue, and by the end of the string the RC analysis is preferred, as Zhang et al. (2000) argue, what would be the reason for the change? This is especially an important question given that the shift violates several structural principles.

Consider the shift from right-branching to relative clause at $N2$ in $V + N1 + de + N2$.³ First, Minimal Revisions (Frazier, 1990) is violated, because the parser revises the current analysis even if it is still legitimate: $N2$ (e.g., *friend* in (1)) can be attached inside the object NP, as shown in the MC and SC structures in Figure 1. Second, Minimal Attachment (Frazier, 1987b) is violated because the parser is required to create many new nodes (S' , NP) to attach $N2$ if it changes to a RC analysis. Third, Late Closure (Frazier, 1987a) is violated because the parser, instead of attaching $N2$ into the object NP currently processed, attaches it high in the structure as the head noun of the RC. Thus, it is clear that there are many structural disadvantages for the switch from a right-branching to a RC analysis.⁴

There seems to be only one advantage for the structural shift at $N2$: completing the gap-filler dependency earlier. Note that if a right-branching parse continues at $N2$, which would be taken as an object noun, the subject gap is left unfilled at this point of processing.⁵ However, if a RC analysis is adopted, $N2$ would be taken as the head noun of the relative clause and the gap would be filled immediately. More importantly, the structural shift is motivated primarily to facilitate semantic processing. If a right-branching structure has been assumed until $N2$, there is no syntactic gap-filler dependency waiting to be completed; the structure is syntactically well-formed even if the filler is not present intrasententially (e.g., *e Waiting for the guest's friend is necessary* for (1)). Therefore, gap-filler processing in this case would not be performed for fulfilling syntactic requirements. It nevertheless provides an interpretation advantage: it offers a referential argument for the subordinate verb as the subject can now co-refer with $N2$ (e.g., *friend*). Hence, if the parser changes from a right-branching to a RC analysis, it would indicate that it is willing to sacrifice syntactic advantage in order to gain an interpretation advantage.

Note that a structural shift at $N2$ also implies that revision is not the last resort (Fodor & Frazier, 1980; Sturt, Pickering, Scheepers, & Crocker, 2001) and existing structural commitments do not restrict the parser's search space for analyses of incoming words (Schneider & Phillips, 2001). The right-branching analyses for (1) are both syntactically and semantically well-formed; thus, structural revision is not required to rescue an implausible current analysis. In addition, if the right-branching parse has been assumed until *friend* in

³We discuss the structural shift at $N2$ here because data from our Experiment 1 indicates that $N2$ is the position where the shift most likely happens. Others may argue that a structural shift could occur at *de* instead of at $N2$ because attaching *de* above the current structure as a RC complementizer would preserve the verb-object relation that has been formed for V and $N1$. There are, nevertheless, several disadvantages to reanalyze at *de*. First, Minimal Attachment and Late Closure are violated because more new nodes (S' & NP vs. PossP) need to be created to support the RC analysis and *de* needs to be attached outside the object NP, the phrase currently processed when *de* is encountered. Second, the uncertainty about the suitability of the upcoming $N2$ as the filler may also decrease the RC preference at that point because a costly reanalysis may result if the expected gap-filler dependency cannot be formed. Our data shows that the right-branching preference is sustained at *de*, suggesting that the disadvantages outweigh the advantages for reanalysis at that position.

⁴We take the structural principles discussed in this paragraph as psychological processes that drive parsing preferences, rather than arguments for a rule-driven human parser.

⁵Principle B of Binding theory would prohibit any noun inside the clause that contains the gap to be the filler (Chomsky, 1981/1993).

(1), the alternative RC parse may not even be in the search space of the parser. Thus, if reanalysis to RC does take place at *friend*, it would indicate that reanalysis can be functional even in a well-formed structure; it is undertaken if it can produce a more meaningful output, such as earlier completion of a gap-filler dependency to create a complete proposition.

Ng and Fodor (2011) investigated the competition of structural economy and gap-filler processing in Chinese sentence comprehension. They employed sentence completion and self-paced reading to look at structural preference for fragments with a subject gap, and found that Chinese readers would adopt a more complex structure in order for it to provide a filler for the gap identified earlier. The current study used the ambiguous *V+NI+de+N2* string for a similar investigation. More importantly, we manipulated *N2*'s semantic property and thus its plausibility as a potential filler for the gap, and examined whether the presence of a potential filler could change the initial analysis assigned to the ambiguous string.

Experiment 1

The aim of this experiment was threefold. First, it re-examined whether the right-branching structure was more preferred than the RC at the beginning of the ambiguous *V+NI+de+N2* string. Second, it investigated whether the initially preferred analysis would persist. Reanalysis was implied if the right-branching analysis was first preferred but the RC analysis prevailed at the end of the string. Third, it examined whether it was the semantic property of *N2* that drove the reanalysis.

Experiment 1a: Written gated sentence completion

Material and methods

Participants: Twenty native Mandarin speakers ($N = 20$; 11 women) were required to continue written sentence fragments by writing. They were 18–42 ($M = 25.8$, $SD = 6.1$) years of age, and were native Mandarin speakers from mainland China. At the time of testing, they were residing in the USA, and the majority was college students.

Stimuli: There were four types of fragments; examples are shown in (2). Completion was required at two positions of *V+NI+de+N2*: *NI* and *N2*. By using gated sentence completion, we would learn whether structural shift occurred within the ambiguous string. See Appendix A for all the stimuli in this experiment.

(2)	a.			
		Det+V+N (Determiner + Verb + Noun) ⁶		
		那个	等待	客人...
		that	wait	guest
		“That (person) waited for the guest.” / “The (person) who waited for the guest...”		
	b.			
V+N (Verb + Noun)				

⁶ The determiner included a classifier, which was always *ge*, the most versatile classifier that is compatible with many animate and inanimate nouns.

等待	客人...
wait	guest
“(Someone) waited for the guest.” / “(Someone) who waited for the guest...”	

c.

V+N1+de+N2[+an] (Verb + Noun1 + de + Noun2[+animate])			
等待	客人	的	朋友...
wait	guest	DE	friend
“Waiting for the guest’s friend...” / “The friend who waited for the guest...”			

d.

V+N1+de+N2[– an] (Verb + Noun1 + de + Noun2[– animate])			
等待	客人	的	答复...
wait	guest	DE	reply
“Waiting for the guest’s reply...”			

The *Det+V+N* fragment, as in (2a), began with a determiner, which itself can be read as a noun, as in *Zhege qiaozha LaoWang yiwān meiyuan* ‘This (person) blackmailed LaoWang for ten thousand US dollars’ (actual completion by a participant). However, without a context that clarifies what the determiner refers to, this reading is not easily available. Thus, the presence of the determiner, which is a typical component of the NP, was expected to bias in favor of the RC reading for the subsequent words, as in *The (person) who waited for the guest...*⁷ This type of sentence tested the effect of a sentence-initial determiner on ambiguity resolution and was important for Experiment 2a, as will be clear later. The *V+N* fragment, as in (2b), contained a verb and a noun and aimed to test the initial analysis assigned to the ambiguous *V+N1+de+N2* string. Ng and Fodor (2011) have used a fragment with only a verb in their sentence completion study, and found a strong right-branching preference. It would therefore be important to test whether the right-branching preference still persisted in a slightly longer fragment: verb+noun. If the preference persisted at that point of parsing, subsequent changes in analysis, if any, could be attributed to words in the later part of the sentence. The comparison of interest for (2a) and (2b) was whether the presence of a clause-initial determiner affected ambiguity resolution. Their continuation patterns, for this reason, would be informative.

The other two types of fragments, as in (2c,d), had the *V+N1+de+N2* pattern, which was syntactically well-formed for both right-branching and RC analyses. The continuation provided would reveal the intended reading of these fragments, as it could be written in favor of an event-reading (compatible with right-branching analysis) or a NP reading (compatible with RC analysis) of the fragment. The only difference of (2c,d) was the semantic property of *N2*. *N2* in (2c) was animate, which was suitable for being the subject of the verb *wait*, providing the semantic basis for the RC reading of the fragment. The right-branching reading was also semantically valid. When creating this type of stimulus, we took great care in lexical selection to balance the plausibility of both readings.⁸ *N2* in (2d) was

⁷ Chinese does not have definite determiners like *the*. The demonstrative in (2a) has a similar function in this context.

⁸ We conducted a plausibility norming study for the two readings and the results will be reported later, in the discussion section of Experiment 1b.

inanimate, and therefore could not be the subject of the verb *wait*. A strong preference for the right-branching reading was thus expected for (2d). By comparing the completion patterns of (2c) and (2d), we would learn whether the semantic property of *N2* was the determining factor for the analysis chosen for this type of sentence fragment. More importantly, by manipulating *N2* and not other words in the fragment, we could more precisely attribute the cause for reanalysis, if any, to the availability of a filler for the subject gap.

Note that the English translations provided for the fragments in (2) do not represent all possible structural analyses for the fragments. Other analyses (e.g., noun-complement clause, gapless relative clause, adjunct clause) are available for some types of fragments. These structural analyses, together with the semantically and syntactically anomalous and the globally ambiguous continuations, were collapsed into the ‘Other’ category in tallying the continuation patterns. The ‘Other’ category accounted for 7% of the completions in this experiment.

Procedure: Each participant received a written questionnaire containing 100 sentence fragments: 48 target fragments (12 in each condition) and 48 fillers. An additional 4 fragments were inserted for covert practice. The 96 fragments (excluding the 4 covert practice items) were pseudo-randomized so that no more than 3 target fragments were presented consecutively. Four lists of stimuli were created, with 12 target fragments from each condition. Participants were instructed to continue the fragments, in writing, in the order presented to create complete sentences.

Two factors were manipulated in the 4 types of fragments: Determiner and *N2* Animacy. However it was not a 2×2 design. The *Det+V+N* and *V+N* fragments differed in the presence or absence of the determiner, whereas the two types of *V+N1+de+N2* fragments differed in the animacy of *N2*. Thus, we performed paired-samples t-tests to compare the *Det+V+N* and *V+N* fragments, and the two types of *V+N1+de+N2* fragments, respectively, to identify the effect of the two factors on the completion patterns.

Results and Discussion—Figure 2 shows the percents of right-branching (sum of main and subject clause) and RC completions for the four types of fragments. It is clear that RC continuations dominated for fragments with a determiner (*Det+V+N*), but right-branching continuations dominated for fragments without a determiner (*V+N*). Paired-samples t-tests confirmed significant differences in both right-branching and RC completions between the two types of fragments (**Right-branching:** $t_1[19] = 12.576, p < .001$; $t_2[47] = 11.461, p < .001$; **RC:** $t_1[19] = 11.727, p < .001$; $t_2[47] = 10.145, p < .001$). Thus, for fragments that begin with a verb and a noun, the right-branching parse is strongly preferred. The addition of a clause-initial determiner, however, significantly increases the RC analysis.

A comparison of the completion patterns for the two types of *V+N1+de+N2* fragments revealed the effect of Animacy. When *N2* was animate, the percents of right-branching and RC completions (53% vs. 41%) were comparable. But when *N2* was inanimate, right-branching completions reached 94%, and there were few RC continuations. Paired-samples t-tests confirmed significant differences between the two types of fragments in both right-

branching and RC completions (**Right-branching:** $t_1[19] = 6.345, p < .001$; $t_2[47] = 8.758, p < .001$; **RC:** $t_1[19] = 6.453, p < .001$; $t_2[47] = 8.343, p < .001$). We further analyzed the percents of right-branching and RC completions for $V+N1+de+N2[+an]$, to see if there was a preference for one structure over the other. Since the two analyses for any one type of fragment were not independent variables, a one-sample t-test was used. First, we calculated the percent of each type of completion against the total of the two. The mean right-branching continuation became 56% and that for RC became 44%. We then performed a one-sample t-test to compare the means against the chance value of 50. Results indicated that the percents of right-branching and RC continuations were not significantly different from chance ($t_1[19] = 0.897, p = .381$; $t_2[47] = 1.155, p = .254$). This suggested that the participants had similar levels of preference for either analysis for $V+N1+de+N2[+an]$.

In sum, results of Experiment 1 indicate that the right-branching preference dominates in the partial input of $V+N$. This is consistent with the findings of Ng and Fodor (2011) that the right-branching analysis is initially preferred. However, the presence of a clause-initial determiner can change the initial analysis in favor of the RC. If the fragment turns out to be $V+N1+de+N2$, the animacy of $N2$ can have a significant impact on ambiguity resolution. If $N2$ is animate, the fragment is equally likely to be analyzed as right-branching and RC. But if $N2$ is inanimate, the right-branching preference persists. This finding provides evidence to support that a structural shift occurs in the presence of a potential filler (an animate $N2$) for the subject gap.

Experiment 1b: Oral gated sentence completion

Results of Experiment 1a suggest that reanalysis can occur between $V+N1$ and $V+N1+de+N2$, which is presumably triggered by an animate $N2$ that facilitates gap-filler completion. But it is also possible that the reanalysis is triggered by the adnominal marker *de*. *De* is an essential component for the RC structure and thus its presence can constitute a strong cue for the RC parse.⁹ Experiment 1b therefore aimed to investigate whether the structural shift occurs at *de* or at $N2$. If the shift occurs at *de*, it would suggest that it is the structural cue but not the presence of a potential filler that triggers the reanalysis. But if the shift occurs at $N2$, it would provide evidence for the effect of gap-filler relation on ambiguity resolution.

Participants were required to continue written sentence fragments orally. The completion modality was different from that in Experiment 1a, where fragment continuations were performed by writing. The modality was changed because oral continuation would produce faster responses and therefore fewer propensities for participants to change their first interpretation of a fragment. Moreover, each participant was required to continue four times more fragments in this experiment than in Experiment 1a. Oral continuations would therefore make the experimental time shorter and hence the experiment more engaging.

⁹ It should be noted that *de* is not a RC maker, per se. Instead, it is a marker for all kinds of noun modifiers, including adjectives, nouns, and RCs. Whether it is a strong cue for the RC parse is thus an empirical question.

Material and methods

Participants: Twenty native Mandarin speakers ($N = 20$; 7 women) aged 18–33 ($M = 25.1$, $SD = 3.7$) participated in this experiment. They were drawn from the same subject pool as the participants in Experiment 1a but did not participate in that experiment. Data of additional 6 participants were excluded from further analysis because of excessive missing responses and incomplete sentences. **Stimuli.** The fragment of interest was $V+N1+de+N2$. Completion was required at every position of the fragment to test possible structural changes across the string. There were four types of fragments, as shown in (3). The $N2$ in (3d) was always an animate noun. The target fragments in this experiment were derived from the $V+N1+de+N2[+an]$ fragments in Experiment 1a.

(3)	a.	V (Verb) 等待 wait
	b.	V+N (Verb + Noun) 等待 客人... wait guest
	c.	V+N+de (Verb + Noun + de) 等待 客人 的 ... wait guest DE
	d.	V+N1+de+N2 (Verb + Noun1 + de + Noun2) 等待 客人 的 朋友... wait guest DE friend

The fragments in (3) formed a set, which were presented on the computer screen to the participants in exactly the same order as (3a) to (3d). In other words, participants would see four progressively longer fragments, and were required to add words after each fragment to create a complete sentence. This design would in principle give participants a strong incentive to maintain the same structure throughout a set of fragments because a change of analysis would entail modifications of established structural and semantic relations of the words, which presumably demands more cognitive effort. But if they still changed the analysis at some point, it would provide strong evidence that the change was important in processing the ambiguous string.

The questionnaire contained 48 sets of target and 48 sets of filler fragments. Each set always consisted of four fragments. Of the 48 filler sets, 24 sets had the $V+N1+de+N2$ pattern in the last fragment, half of which favored the RC analysis and the other half favored the right-branching analysis. The rest of the filler sets contained fragments in various structures and they invariably contained an overt subject. The target and filler sets were pseudo-

randomized so that no more than two target or filler sets were presented consecutively to a participant.

Procedure: Participants were required to continue written sentence fragments orally. As mentioned before, stimuli were presented as sets of four fragments, with each fragment progressively longer than the previous one. The whole experiment was self-paced; there was no time limit on each continuation. But participants were instructed not to pause within each set of fragments. Participants' responses were recorded for later categorization by experimenters.

Same as Experiment 1a, fragments were categorized as right-branching (sum of main and subject clauses) and RC analysis based on their completions. Other structural analyses, the globally ambiguous continuations, incomplete sentences, and glitches were collapsed into the 'Other' category in tallying the continuation patterns. The 'Other' category accounted for 7% of the target completions.

Results and Discussion—Figure 3 shows the percents of right-branching (sum of main and subject clause) and RC completions for the four types of fragments. The right-branching completion clearly dominated at the fragment-initial, single-verb position and then gradually decreased as the fragment became longer. At the $V+N+de$ position, the right-branching analysis still accounted for 70% of completions. But at the $V+N1+de+N2$ position, it only accounted for 38% of completions. To the contrary, the RC completion was negligible at the single-verb position, but accounted for 56% of completions at $V+N1+de+N2$. Results of one-way ANOVA confirmed that both right-branching and RC completions were significantly different among the four types of fragments (**Right-branching:** $F_1[3,76] = 60.400, p < .001$; $F_2[3,188] = 88.826, p < .001$; **RC:** $F_1[3,76] = 55.857, p < .001$; $F_2[3,188] = 131.049, p < .001$). Post-hoc Tukey tests showed that the percent completion of every type of fragment was significantly different from the others in item analysis ($ps < .036$). In subject analysis, all comparisons were significantly different ($ps < .020$), except for the V and $V+N$ fragments in the right-branching completions, and V and $V+N$, and $V+N$ and $V+N+de$ fragments in the RC completions.

We further looked at the number of right-branching and RC analysis at the $V+N1+de+N2$ position. If only the two types of continuations were counted, the right-branching analysis accounted for 40% of total completions and the RC analysis 60%. A one-sample t-test was performed to compare these means against the chance value of 50. The difference was significant ($t_1[19] = 2.883, p = .010$; $t_2[47] = 2.863, p = .006$). Thus this finding was different from that in Experiment 1a, where the two analyses were found to be equally preferred for the $V+N1+de+N2[+an]$ fragment.

To summarize, results of Experiment 1b indicated that the right-branching analysis was initially preferred for $V+N1+de+N2$, but at the end of the string the RC parse increased significantly. Moreover, although *de* facilitated the RC parse (the RC analysis accounted for 21% of completions at $V+N1+de$, compared to 2% at V and 10% at $V+N$), the main trigger for reanalysis occurred at $N2$. When $N2$ was an animate noun and therefore a suitable filler for the subject gap, the RC completion increased to 56%, which was significantly more than

the proportions of RC continuations from all three previous positions. This finding shows that it is the semantic property of *N2* that triggers a structural change in favor of RC at the end of *V+N1+de+N2*.

Two issues related to these findings need to be addressed here. First, why is the RC analysis preferred over the right-branching analysis at *V+N1+de+N2* in Experiment 1b, but not so for the *V+N1+de+N2[+an]* fragment in Experiment 1a? There can be several reasons for this difference. First, Experiment 1a requires written completion and Experiment 1b oral completion. The modality change affects both the speed of response and the register or formality of language use, e.g., writing is generally considered a more formal language use than speaking. Moreover, fragments are presented in different ways in the two experiments. In this experiment participants are presented with sets of fragments, but in Experiment 1a fragments presented to participants are not clearly related to each other. It is not clear what reason causes the differences in observed effects in the two experiments. What is clear, though, is the RC analysis increases significantly at *N2* for *V+N1+de+N2* when *N2* is a potential gap-filler.

Another issue is the possible plausibility difference for *N2* to be the subject or object in the *V+N1+de+N2[+an]* fragments. For example, if *N2* is more likely to be the subject for the verb, the RC parse would be facilitated. But if *N2* is more likely to be the object, the right-branching parse would be facilitated. To look into this possibility, we conducted a plausibility norming study, in which 20 native Mandarin speakers were required to judge, on a Likert scale of 1 to 5 (1=not plausible and 5=very plausible), the plausibility of the event described in a sentence (similar to the norming study in Zhang, et al., 2000). The words in the *V+N1+de+N2* fragments used in Experiment 1b were rearranged to yield two types of sentences, each of which represented the respective right-branching and RC reading of a fragment. For example, for (3d), the two conditions were: *someone waited for the guest's friend* (the right-branching reading) and *the friend waited for the guest* (the RC reading). Two versions of the questionnaire were created, each containing 24 target sentences that corresponded to the right-branching reading and 24 target sentences that corresponded to the RC reading. Additional 48 fillers were included in the questionnaire. Half of them had the sentence pattern of the right-branching reading (e.g., *someone served the restaurant's waiter*.) and the other half the RC reading (e.g., *the worker fired the boss*.). All of the fillers were created to describe less plausible events.

The results showed that the sentences compatible with the right-branching reading had a mean rating of 3.8 (SD = 0.6) and the sentences compatible with the RC reading had a meaning rating of 4.2 (SD = 0.7). Results of the Wilcoxon signed-ranks test showed a significant difference ($Z = 3.833, p < .001$). Thus, the lexical composition of *V+N1+de+N2* seemed to favor the RC reading. Then we further investigated whether the plausibility difference for the two readings was psychologically real; in other words, whether or not it affected behavior. We performed Pearson's correlation on the percent RC completions (out of total of only MC, SC, and RC completions) in Experiments 1a and 1b and the mean rating differences of the two readings for the fragments. A positive correlation would indicate that the more plausible the RC reading was for a given fragment the more RC continuations the Mandarin speakers would produce. The results showed no correlations between the ratings

and the proportion of RC continuations in either the written or spoken sentence completion studies ($ps > .086$). There was, however, a strong positive correlation between the two sentence completion tasks in the percent RC completions for the $V+N1+de+N2[+an]$ strings ($r[48] = 0.665, p < .001$). This indicated that the participants in the two tasks had a similar level of RC preference for a particular fragment, even if this preference was not related to the plausibility of the RC reading. An additional correlation analysis was performed on those sentences in the norming study with at least one level of difference (on the Likert scale of 5 levels) in the mean rating scores for the two readings. Ten sentences with mean rating differences ranging from -1 (preferred right-branching analysis) to 1.7 (preferred RC analysis) were selected for this analysis. Their mean rating differences were correlated with the percent RC completions in the two tasks. This analysis was intended to examine if a plausibility effect existed for the more extreme items. Still, no correlations were found ($ps < .222$). Thus, although the plausibility ratings for the right-branching and RC readings were reliably different, with the RC being a more preferred reading, there was no evidence that this plausibility difference actually biased participants' structural preference for the $V+N1+de+N2[+an]$ fragments. Instead, the completion patterns for the written and oral tasks were consistent with each other.

Experiment 2

This experiment aimed to collect on-line reading time data for the $V+N1+de+N2$ string and the disambiguation sentence segment that followed. Results from Experiment 1 indicate that the right-branching analysis is initially preferred for this type of fragment. But if $N2$ is animate, the RC analysis increases considerably. While sentence completion can reveal the preferred reading for a fragment, it combines comprehension and production, which may not resemble normal reading comprehension. Thus, it is necessary to investigate if similar findings are also observed in natural reading tasks. Experiment 2 investigated whether the structural shift from right-branching to RC in $V+N1+de+N2$ actually occurred on-line. We hypothesized that the reason for the shift was to fill the subject gap earlier, despite the numerous structural disadvantages of the RC.

Experiment 2a: Self-paced reading 1

Material and methods

Participants: Participants were native Mandarin speakers ($N = 36$; 18 women) and were 19–45 ($M = 28.9, SD = 6.2$) years of age. None of them participated in Experiment 1. Data from additional 7 participants were excluded from analysis because of excessive errors ($>25\%$) on the comprehension questions.

Stimuli: This experiment employed self-paced word-by-word (not character-by-character) reading, in which participants read, at their own pace, one word at a time and the reading time of each word was registered in milliseconds by the computer. The stimulus is shown in (4). The slash (/) indicates where a sentence was divided into words. The $V+N1+de+N2$ fragments from Experiment 1b were the target segments in this reading task, but were completed as full sentences. See Appendix A for all the stimuli in this experiment.

(4)	a.	[+det,+an] (+determiner, +animate) 那个 / 等待 / 客人 / 的 / 朋友 / 的 / 主人 / 很焦急。 that wait guest DE friend DE host very-anxious “The host who waited for the guest’s friend was very anxious.”
	b.	[+det,-an] (+determiner, –animate) 那个 / 等待 / 客人 / 的 / 答复 / 的 / 主人 / 很焦急。 that wait guest DE reply DE host very-anxious “The host who waited for the guest’s reply was very anxious.”
	c.	[–det,+an] (–determiner, +animate) 等待 / 客人 / 的 / 朋友 / 的 / 主人 / 很焦急。 wait guest DE friend DE host very-anxious “The host who waited for the guest’s friend was very anxious.”
	d.	[–det,-an] (–determiner, –animate) 等待 / 客人 / 的 / 答复 / 的 / 主人 / 很焦急。 wait guest DE reply DE host very-anxious “The host who waited for the guest’s reply was very anxious.”

There were four sentence types; all contained the $V+N1+de+N2$ segment, which could be temporarily ambiguous between the right-branching and RC parse. Another *de* (*de2*) and a third noun (*N3*) were added after the segment. *De2* here would lead to a strong right-branching preference for the previous $V+N1+de+N2$ segment. This preference was clearly shown in the results of a norming study, as will be discussed below. For all sentence types, the final preferred analysis was a RC, with *host* being the filler and *guest’s friend/guest’s reply* being the object of the subordinate verb *wait*. Figure 4 (Structure C) illustrates the structure of the critical segment in (4).

The stimulus sentences comprised a 2×2 Latin square design crossing the factors Determiner (presence vs. absence) and *N2* Animacy (animate vs. inanimate). Results of Experiment 1 showed that for a fragment that began with a verb, the right-branching analysis was initially preferred, unless it was preceded by a determiner, in which case the RC analysis was more preferential. Thus, we expected that the RC analysis would be adopted early for (4a,b) and the right-branching analysis for (4c,d). If *N2* turned out to be an animate noun, as *friend* in (4a,c), it was expected to be treated as the head noun of the NP and therefore the gap-filler for (4a). The critical condition was (4c). The right-branching analysis was presumably to be initially preferred. At *N2*, the animate noun provided an opportunity to fill the subject gap but *only if* the RC analysis was adopted. Which analysis was actually adopted at *N2* for (4c) would be revealed at the following word, *de2* (see the discussion below). On the other hand, the inanimate *N2* (*reply*) in (4b,d) was expected to be treated as the object of *waited*, regardless of the presence or absence of a clause-initial

determiner. This is because *reply* is semantically unsuitable for being the filler even if the RC analysis was assumed with a subject gap waiting to be filled, as expected for (4b).

When *de2* subsequently appeared, it would produce a strong preference for the right-branching reading for $V+N1+de+N2$, so that *N2* (both *friend* and *reply*) could not be the head noun for a RC. Instead, *N2* should be the object noun inside the subordinate clause, as in a right-branching analysis, and the noun following *de2* (i.e., *N3*) was likely to be the head noun. As a result, reanalysis was required if a RC had been formed to modify *N2*, but little reanalysis was needed if the right-branching analysis had been assumed (see Figure 4). Based on that, we predicted that *de2* and *N3* in (4b,d) would be read faster than those in (4a). As for (4c), if the RC analysis was adopted at *N2*, it would be read similarly to (4a). If the right-branching analysis was sustained at *N2*, it would be read similarly to (4b,d). Hence, by comparing the reading times of *de2* and *N3* in the four conditions, we would know whether a structural shift actually happened at *N2* for (4c).

The $V+N1+de+N2+de+N3$ segment in (4c) could have two alternative analyses (see Figure 5). First, $V+N1+de+N2+de+N3$ could be taken as a right-branching structure for (4c), which would mean *Waiting for the guest's friend's host*. Another analysis was to take *friend's host* as a NP, and the gap-filler would be either *friend* or *host*. The sentence in (4c) would then mean *The friend's host who waited for the guest was very anxious*. A structure disambiguation norming study was conducted to examine the analysis that was actually assigned to the target sentences in this experiment. Twenty native Mandarin speakers who did not participate in the reading experiment were required to indicate their preferred interpretation for sentences like (4). They were given three choices: 1) *The host waited for the guest's friend*, 2) *Someone waited for the guest's friend's host*, and 3) *The friend's host waited for the guest*. The results indicated that 91% of the time the preferred interpretation was *The host waited for the guest's friend*, the intended interpretation shown in Figure 4, Structure C. Thus, there was a clear preference for taking *N3* as the head noun for the relative clause analysis.

It could also be argued that the reading time data of *de2* might only reflect the lexical difference at *N2* rather than the reanalysis discussed above. If the animate nouns had lower usage frequency than the inanimate nouns, the reading slowdown found at *de2* could result from a spillover of the frequency effect rather than the structural shift that we claimed. To consider this possibility, we researched the usage frequency of the *N2* nouns, using the SUBTLEX-Chinese word frequency database developed by Cai and Brysbaert (2010). The averaged per/million frequencies for the animate and inanimate nouns were 177 (*SD*: 276) and 63 (*SD*: 153), respectively, and this difference was significant in an independent-samples t-test ($t[93] = 2.51, p = .014$).¹⁰ This could presumably cause a longer reading time for the inanimate than the animate sentences, contrary to our predictions. Thus, if we obtained the predicted results, the lexical difference of *N2* could not be the cause.

The stimuli contained 48 target sentences (12 in each sentence type), 96 fillers, and additional 4 sentences for covert practice. The fillers included 48 sentences that contained

¹⁰ The frequency data of one animate noun was not in the database.

the $V+N1+de+N2+de+N3$ segment but all turned out to be subject clauses. This was designed to counterbalance the probability of the SC and RC reading for sentences with the $V+N1+de+N2+de+N3$ segment. Out of these 48 fillers, half of them had an animate $N2$ and the other half had an inanimate $N2$, but $N3$ was always inanimate. The other 48 fillers contained only the $V+N1+de+N2$ segment, thereby tempering the participants' expectation that there would always be $N3$ in the sentences. Out of these 48 fillers, half contained a SC and the other half contained a RC. For those filler sentences that contained a SC, half of them had an animate $N2$ and the other half had an inanimate $N2$. For those that contained a RC, half of them contained a clause-initial determiner and the other half did not contain a clause-initial determiner. Stimuli were pseudo-randomized so that no more than two target sentences were presented consecutively. Four lists were created. Participants were given oral instruction in Mandarin on the task demands, and 5 additional sentences for practice.

Procedure: Stimuli, in 18-point size and black ink on a white background, were presented by E-Prime 2.0, and reaction times were collected through the serial response box designed by Psychology Software Tools, Inc. Each sentence began with a fixation cross in the center of the screen. Participants were instructed to press the rightmost button on the response box to begin a sentence. The first word replaced the fixation cross. Each subsequent word, triggered by the same button press, was presented in the same place, replacing the previous word. Without intervention, each word disappeared after 5 seconds. The last word of a sentence was presented with a period, “。” in Chinese. To maintain the participants' attention, a comprehension question followed half of the experimental sentences. The question contained a declarative sentence. Participants were asked to judge, within 20 seconds, whether the information in the declarative sentence was consistent with the information in the previous sentence. They answered by pressing the two leftmost buttons on the response box. No feedback was provided. A fixation cross reappeared after the response, readying the participant for the next sentence.

In data analysis, reading times below 100 msec or beyond the time limit (5 seconds) were discarded. Moreover, reading times more than 2 standard deviations away from the mean reading time of an individual participant were changed to the mean reading time of that participant, plus or minus 2 standard deviations. All this affected 513 data points (4.9%) in the target segment (i.e., $N1+de+N2+de+N3+[N3+1]$, where $N3+1$ was the word immediately following $N3$). Linear mixed-effects modeling through SPSS's linear mixed model analysis was employed to account for the effects of Determiner (presence vs. absence) and $N2$ Animacy (animate vs. inanimate) on the reading times. The models took Determiner and Animacy as fixed effects and participants and items as random effects, using the maximal random effects structure, i.e., both random intercepts and random slopes of participants and items contributed to the covariance structure (scaled-identity structure) of the data (Barr, Levy, Scheepers, & Tily, 2013). The restricted maximum likelihood (REML) technique was used to estimate the parameters of the fixed and random effects.

Results and Discussion—The mean accuracy to the comprehension questions of all experimental sentences was 87.8% (SD : 5.6). Table 1 shows the accuracy rates and reaction times as per condition of the target sentences. There were no main effects or interactions in

the accuracy rates but there was a main effect of Animacy in the reaction times. The questions to the sentences with an inanimate *N2* were answered faster than those with an animate *N2* ($F[1,35] = 14.276, p = .001$). However, this finding should be interpreted with caution because 6 out of the 24 comprehension questions for the target sentences were different between the animate and inanimate conditions (in the use of the animate or inanimate *N2* in the questions).

Figure 6 shows the reading times for the target words. No significant reading time differences were found at the three words (*N1*, *de1*, *N2*) preceding the disambiguation segment ($ps > .228$). A main effect of Animacy was observed at the disambiguating *de2* and two subsequent regions (***de2***: $F[1,178] = 5.645, p = .019$; ***N3***: $F[1,145] = 18.451, p < .001$; ***N3+I***: $F[1,202] = 21.556, p < .001$). Sentences with an animate *N2* were read slower than sentences with an inanimate *N2*. There was no main effect of Determiner in any critical region. The only significant Animacy x Determiner interaction was found at *N3* ($F[1,1516] = 5.399, p = .020$). Planned comparisons revealed a main effect of Animacy for both $[+det]$ and $[-det]$ sentences ($[+det]$: $F[1,211] = 23.780, p < .001$; $[-det]$: $F[1,212] = 8.605, p = .004$), and no significant difference in the effects of Determiner for both $[+an]$ and $[-an]$ sentences ($ps > .259$). This indicated that the Animacy effect was present for sentences with and without the determiner, with the effect larger for sentences with the determiner.

These results suggested that an animate *N2* caused a reading slowdown at the following *de2*, and processing difficulty persisted in two following words: *N3* and *N3+I*. This in turn indicated that the RC analysis had been adopted by *de2* for the two animate sentences, with *N2* being the head noun and the filler for the subject gap. This analysis turned out to be incorrect when *de2* appeared. For the inanimate sentences, *N2* could not be the filler for the gap and consequently, the right-branching analysis persisted. The subsequent appearance of *de2* thus caused little reanalysis of the partial input.

Based on the findings from Experiment 1 that show an initial preference for a right-branching parse in the absence of a clause-initial determiner, the adoption of the RC at *N2* for $[-det, +an]$ implies a reanalysis from right-branching to RC. This reanalysis happens only when *N2* is animate and therefore a good filler for the gap.

The determiner effect was observed only at *N3*, where it interacted with Animacy. The Animacy effect was present for both $[+det]$ and $[-det]$ sentences but the effect was larger for the former. The co-occurrence of the determiner and animate *N2* might increase the difficulty in reanalyzing $V+N1+de+N2$ from RC to right-branching. Thus, the determiner only affected reanalysis but not ambiguity resolution for $V+N1+de+N2$. This finding is consistent with that in Wu, Kaiser, & Andersen (2009), who found late determiner effects in processing RC constructions in Chinese.

In order to further investigate whether plausibility of *N2* as the subject or object contributed to the RC analysis, we removed the 10 sentences that had the largest difference in the plausibility ratings of the RC and right-branching readings in the norming study discussed previously. The Animacy effects ($ps < .001$) at the *N3* and *N3+I* were unchanged, and the Animacy effect at *de2* was trending significant ($F[1,194] = 3.216, p = .074$). Thus, *N2*

plausibility was unlikely to contribute to the observations. In addition, because the target and filler sentences in this experiment did not include simple main clause sentences, the whole experiment might inadvertently bias the readers in favor of more complex analyses. To further look at this possibility, we performed a split-half analysis on the reading times of the three critical regions (*de2*, *N3*, & *N3+1*) to examine if the results were already present in the first half of the experiment, before the participants fully eliminated the simple main clause analysis for the sentences in this experiment. Results of ANOVA based on subject reading time data showed main effects of Animacy at *N3* and *N3+1* ($ps < .009$). The animacy manipulation at *de2* failed to reach significance ($F[1,35] = 2.425, p = .128$), but the trend was consistent with the whole-experiment analysis, with the mean reading time difference of the [+*an*] and [−*an*] conditions at 28 ms in the split-half analysis and that at 36 ms in the whole-experiment analysis. Thus, it was unlikely that the absence of main clause sentences affected the reading time data observed for the critical regions.

Finally, given that sentences like (4) can possibly be analyzed as *The friend's host who waited for the guest was very anxious* (structure on the right in Figure 5), why would Chinese readers give up on an established gap-filler dependency at *de2* with *friend* as the filler and prefer the final analysis with *host* as the filler, as shown in the structure disambiguation norming study? It is not entirely clear why a simple NP (*N3*) is more preferred than a complex NP (*N2+de+N3*) to be relativized in Chinese.¹¹ There could be some structural and semantic constraints that override the urgency of filling a gap and make the simple NP a more preferable analysis. More research is needed to understand this parsing preference.

In sum, we found that Chinese readers change from a right-branching to a left-branching structure to make a filler available earlier for an identified gap. This happens notwithstanding that a continuation of the right-branching structure is still legitimate. Crucially, this occurs on-line, at the processing of the noun that is a potential filler. These findings suggest that the parser prioritizes providing referential arguments for a proposition through filling a gap over observing structural principles.

Experiment 2b: Self-paced reading 2

Results of Experiment 2a provide real-time reading data that supports a RC analysis at the end of the ambiguous *V+N1+de+N2* string if *N2* is an animate noun. Combined with the results of Experiment 1, the data suggests an initial preference for the right-branching analysis for *V+N1+de+N2* and a later reanalysis to the RC at *N2*. However, one may argue that the sentences in Experiment 2a contain the complex *V+N1+de+N2+de+N3* string and thus may not reflect normal sentence comprehension. Moreover, the effects observed at *de2* and the two subsequent words may only reflect the processing difficulty caused by two preceding animate nouns, as animacy effect has been evidenced in the processing of Chinese relative clauses (He & Chen, 2013). Third, although *N2* animacy may be related to gap-filler processing, it does not constitute direct evidence that it is the presence of the gap that

¹¹ There seems to be a general dispreference for a Chinese noun to be modified by two types of phrase (e.g., *piaoliang* 'beautiful' and the RC in the following examples) that are not semantically related. Thus, *e Paobu de piaoliang de nühai...* 'The beautiful girl who runs...' sounds odd but *e Ai daban de piaoliang de nühai...* 'The beautiful girl who likes to preen herself...' is fine.

contributes to the RC analysis at the end of $V+NI+de+N2$. Experiment 2b was designed to address these concerns.

Material and methods

Participants: Participants ($N = 36$; 17 women) were 18–41 ($M = 25.1$, $SD = 5.1$) years of age. None of them had participated in Experiment 2a. Data of additional 5 participants were excluded from analysis due to excessive errors (>25%) on comprehension questions and equipment failure.

Stimuli: Same as Experiment 2a, it was a self-paced word-by-word reading experiment. The stimulus is shown in (5). The slash (/) indicates where a sentence was divided into words. The $V+NI+de+N2$ string in each sentence was the same as those used in Experiments 1a and 2a and was a subject clause in the final analysis. It was followed by a main clause in the present experiment, rather than by $de2$ and $N3$ as in Experiment 2a. Appendix B lists all the stimuli used in this experiment.

- (5) a.

[+subj, +an] (+subject, +animate)¹²
我们 / 等待 / 客人 / 的 / 朋友 / 已经 / 很久了。
we wait guest DE friend already long-time
“It has been a long time for us to wait for the guest’s friend.”

- b.

[+subj, –an] (+subject, –animate)
我们 / 等待 / 客人 / 的 / 答复 / 已经 / 很久了。
we wait guest DE reply already long-time
“It has been a long time for us to wait for the guest’s reply.”

- c.

[– subj, +an] (– subject, +animate)
等待 / 客人 / 的 / 朋友 / 已经 / 很久了。
wait guest DE friend already long-time
“It has been a long time to wait for the guest’s friend.”

- d.

[– subj, –an] (– subject, –animate)
等待 / 客人 / 的 / 答复 / 已经 / 很久了。
wait guest DE reply already long-time
“It has been a long time to wait for the guest’s reply.”

The sentences in (5) differed in the presence or absence of a sentence-initial subject and $N2$ animacy. The presence of an overt subject in (5a,b) would block the RC parse for $V+NI+de$

¹² Some people might think that the sentence in (5a) has the structure like the English sentence *We have been waiting for the guest’s friend for a long time*, with *long-time* being an adjunct for the verb phrase. However, in Chinese, such a structure requires verb reduplication (Huang, 1982), resulting in this sentence word order: we wait guest *de* friend already waited longtime. Chinese does not generally allow more than one postverbal element.

+N2 from the beginning of the sentence; as a result, only the right-branching parse was possible. If two animate nouns (*guest & friend* in $V+N1+de+N2$) did not produce more processing difficulty than one animate noun, the reading times for (5a,b) would be similar. If processing two animate nouns was more difficult than processing one animate noun, (5a) would produce a longer reading time than (5b). These two sentences were used as control sentences for comparison with those in (5c,d). In the absence of an overt subject, (5c,d) could be temporally ambiguous between the right-branching and RC analysis. The animate N2 in (5c) could sustain this ambiguity at that point of processing, but the inanimate N2 in (5d) would disambiguate the construction in favor of the right-branching analysis. When the main clause (i.e., the *already-long-time* segment in (5)) appeared, it would become clear that the sentences in (5) contained a subject clause (see below for the disambiguation). If the animate N2 had no effect on the structural analysis of (5c), the main clause in (5c) would be processed similarly to that in (5d), where the right-branching analysis was presumably adopted at N2. But if the animate N2 increased the RC analysis for $V+N1+de+N2$ in (5c), the subsequent appearance of the main clause would force reanalysis, which could produce a reading slowdown in the main clause for (5c), compared to that in (5d). In brief, if it were the structural reanalysis for (5c) that produced processing difficulty, an Animacy x Subject interaction would be observed in the disambiguating main clause for the sentences in (5), with a slower reading time for (5c) than the other three sentences. If, on the other hand, it was the presence of two animate nouns that produced processing difficulty, there would only be a main effect of Animacy, but not an Animacy x Subject interaction.

The disambiguation for the target sentences in this experiment relied on the meaning of the main clause as a whole that supported the SC analysis, rather than a specific point when the difficulty of attaching a new word into the structure arose, as was the case for *de2* in Experiment 2a. For example, the sentence in (5c) would be semantically odd if ‘long-time’ was predicated on ‘the friend’ but would make sense if ‘long-time’ was predicated on ‘the waiting.’ The disambiguation was therefore likely to spread out over several words, and there might not be a consistent position in the main clause across the target sentences where the participants became certain that the subordinate clause was a SC rather than a RC. As a result, we analyzed the reading times of the first few words in the main clause, the average reading time of a word in the main clause, and the reading time of the sentence-final word, to determine if reanalysis occurred in (5c).

The stimuli contained 48 target sentences (12 in each condition) and 96 fillers. The fillers included 48 sentences with the $V+N1+de+N2$ segment, half of which contained an ambiguous RC and the other half contained an unambiguous RC. The other 48 filler sentences contained a main clause, half with an overt subject and the other half without an overt subject.

Procedure: The stimulus sentences comprised a 2×2 Latin square design crossing the factors Subject (presence vs. absence) and N2 Animacy (animate vs. inanimate). Data trimming and analysis were identical to those of Experiment 2a, and 623 reading time outliers (4.6%) in the target sentences were changed. Mixed-effect modeling was employed to identify the Subject and Animacy effects.

Results and Discussion—The mean accuracy to the comprehension questions of all experimental sentences was 86.5% ($SD: 3.7$). Table 1 shows the accuracy rates and reaction times as per condition of the target sentences. There was a main effect of Animacy in the accuracy rate ($F[1,35] = 15.800, p < .001$). The comprehension questions to sentences with an animate $N2$ were answered less accurately than those to sentences with an inanimate $N2$. In addition, there was a Subject x Animacy interaction in the reaction times ($F[1,35] = 4.604, p = .039$). Pairwise comparisons indicated that the $[-subj, +an]$ condition elicited longer reaction times to the comprehension questions than the $[+subj, +an]$ ($F[1,35] = 4.777, p = .036$) and the $[-subj, -an]$ conditions ($F[1,35] = 8.163, p = .007$). Note that these results should be interpreted with caution because, like Experiment 2a, the comprehension questions were not exactly the same across the four conditions for each sentence.

Figure 7 shows the reading times of the target sentences, excluding the overt subject in the two $[+subj]$ sentences. The words in the main clause are labeled as MC followed by an Arabic number that indicates their position in the clause, e.g., $MC1$ is the first word in the main clause and $MC2$ is the second word. The number of words in the main clause segment of the target sentences varied from one to seven words.

There was no main effect or interaction in the four words preceding the main clause ($V, NI, de, N2$) ($ps > .169$). Main effects of Animacy and Animacy x Subject interactions were found in the reading times of the first four words in the main clause, the average reading time of a word in the main clause, and the reading time of the sentence-final word:

- At $MC1$, a main effect of Animacy ($F[1,178] = 6.594, p = .011$) was observed. Sentences with an animate $N2$ were read slower than sentences with an inanimate $N2$.
- At $MC2$, a main effect of Animacy ($F[1,225] = 5.071, p = .025$) and an Animacy x Subject interaction ($F[1,1503] = 5.695, p = .017$) were observed. Pairwise comparisons showed a significant difference in the reading times between the two $[-subj]$ conditions ($F[1,357] = 9.641, p = .002$) but not between the two $[+subj]$ conditions ($F[1,358] = 0.779, p = .378$). Sentences with an animate $N2$ were read slower than sentences with an inanimate $N2$ only for the sentences without an overt subject ($[-subj]$ conditions).
- At $MC3$, a Subject x Animacy interaction ($F[1,1239] = 4.653, p = .031$) was observed. Pairwise comparisons indicated a significant difference in the reading times between the two $[-subj]$ conditions ($F[1,353] = 6.005, p = .015$) but not between the two $[+subj]$ conditions ($F[1,351] = 0.172, p = .678$). Sentences with an animate $N2$ were read slower than sentences with an inanimate $N2$ only for the sentences without an overt subject ($[-subj]$ conditions).
- At $MC4$, a Subject x Animacy interaction ($F[1,1000] = 7.322, p = .007$) was observed. Pairwise comparisons indicated a significant difference in the reading times between the two $[-subj]$ conditions ($F[1,302] = 7.258, p = .007$) but not between the two $[+subj]$ conditions ($F[1,302] = 0.095, p = .758$). Sentences with an animate $N2$ were read slower than sentences with an inanimate $N2$ only for the sentences without an overt subject ($[-subj]$ conditions).

Statistical analyses were not performed for the words following *MC4* because only 16 out of 48 target sentences had *MC5*. The small number of sentences could introduce excessive noise into the data.

Besides the word-by-word analyses, we also examined the average reading time of a word in the main clause and the reading time of the sentence-final word. The sentence-final word was presented with a period, which would indicate the end of the sentence. This position could reflect the sentence wrap-up effect (Just & Carpenter, 1980), where the readers integrated all the words in the sentence to obtain an interpretation. Figure 8 shows, from left to right, a) the reading times for a word averaged across all words in the main clause; and b) the reading times of the sentence-final word, in the four target conditions.

For the reading times averaged across all words in the main clause, a main effect of Animacy ($F[1,177] = 7.972, p = .005$) and an Animacy x Subject interaction ($F[1,1527] = 5.424, p = .020$) were found. Pairwise comparisons showed no Animacy effect for the two $[+subj]$ conditions ($F[1,231] = 3.285, p = .071$). However, the Animacy effect was present for the two $[-subj]$ conditions ($F[1,231] = 12.015, p = .001$), where sentences with an animate *N2* were read slower than sentences with an inanimate *N2*. A similar reading time pattern was found for the sentence-final word: a main effect of Animacy ($F[1,165] = 6.258, p = .013$) and an Animacy x Subject ($F[1,1518] = 11.488, p = .001$). In pairwise comparisons, a reliable reading time difference was observed between the two $[-subj]$ conditions ($F[1,227] = 13.108, p < .001$), but not between the two $[+subj]$ conditions ($F[1,227] = 0.981, p = .323$). Sentences with an animate *N2* were read slower than sentences with an inanimate *N2* only for the sentences without an overt subject ($[-subj]$ conditions).

Finally, we also investigated the possible effect of *N2* plausibility on the structural preference for the subordinate clause in these sentences. Like the analysis we performed for Experiment 2a, we reanalyzed the reading times of the first four words in the main clause and the sentence-final word and the mean reading times per word in the main clause, after removing the 10 sentences with the largest difference in the plausibility ratings of the RC and right-branching readings. All the animacy and interaction effects were not affected. Thus, once again, the plausibility difference between the two analyses was unlikely to be the contributing factor to the observed effects.

In sum, we found that processing two animate nouns in $V+N1+de+N2$ could be more difficult than processing one animate and one inanimate noun, as reflected in the Animacy effect observed at *MC1*. However, more importantly, this animacy effect persisted only for the sentences without an overt subject, as the $[-subj, +an]$ condition was found to elicit slower reading times than the $[-subj, -an]$ condition at *MC2*, *MC3*, *MC4*, and the sentence-final word. This animacy effect was not observed in these regions for the sentences with an overt subject ($[+subj]$ conditions). Thus, noun animacy alone could not explain the persistent reading slowdown for the $[-subj, +an]$ sentences. Instead, the enduring difficulty was likely caused by the reanalysis from RC to right-branching for the $V+N1+de+N2$ segment.

General Discussion

A series of behavioral studies was conducted to investigate the effect of gap-filler relation on the processing of the ambiguous $V+NI+de+N2$ string in Chinese. The critical question was whether the presence of a potential filler for an identified subject gap would lead Chinese readers to adopt a structurally more complex analysis, which would violate structural principles but maximize the interpretation of the partial input. Experiment 1 employed gated sentence completion to examine the preferred analysis at each position in $V+NI+de+N2$. Experiment 2 employed self-paced word-by-word reading to look at the effects of disambiguation in the words following the string.

Results of Experiment 1 showed that native Mandarin speakers preferred the right-branching parse for the $V+NI+de+N2$ string up to *de*. If *N2* was an inanimate noun and therefore was not a potential filler for the subject gap, the right-branching analysis was sustained. But if *N2* was an animate noun and hence a potential filler, Chinese readers would often give up the right-branching analysis in favor of the RC.

Experiment 2 employed self-paced word-by-word reading to verify whether the structural revision found in Experiment 1 occurred on-line. The $V+NI+de+N2$ string was disambiguated in different ways in Experiments 2a and 2b. In Experiment 2a, an additional *de* was added after *N2*, forcing a revision of $V+NI+de+N2$ if a RC had been formed with *N2* as the filler for the gap. In Experiment 2b, the main clause that followed $V+NI+de+N2$ was semantically more compatible with the right-branching parse for the string, thus forcing a revision if the RC had been assumed. In both experiments, longer reading times were observed in the disambiguation segment following $V+NI+de+N2$, only if the string contained a subject gap and an animate *N2* as a potential filler in the RC analysis.

Results of Experiments 1 and 2 converge to support that the Chinese parser would change a preferred analysis to facilitate gap-filler processing, despite the fact that doing so would violate structural principles. This finding echoes those in Ng and Fodor (2011), where a structurally simpler analysis is discarded in favor of the one that can provide a filler for an identified gap.

At first glance, this finding contradicts that in de Vincenzi (1991), where in Italian sentences like *Ieri pomeriggio ha richiamato il venditore per chiedere/offrire uno sconto ...* (Yesterday afternoon has calledback the seller to ask-for/offer a discount...), *il venditore* ‘the seller’ can be a filler for the subject gap because Italian allows for post-verbal subjects. But a reading slowdown was observed at *per offrire uno sconto*, compared to *per chiedere uno sconto*, suggesting an unexpected subject reading of *il venditore* (because the seller is more likely to offer a discount rather than ask for a discount). This result suggests that *il venditore* is not taken as the gap-filler when it is encountered. However, this does not pose as a contradiction to our findings, given the hypothesis that the parser would fill a gap only if it could provide semantic advantage. If the post-verbal NP in Italian became the filler for the subject gap, the object NP would be missing, in which case the proposition of the sentence was still incomplete. The object-to-subject reanalysis would then be a zero-sum reanalysis in terms of fulfilling interpretation requirements. In the case of our Chinese

sentences, *N1* can serve either as the object NP or as a noun modifier; as a result, treating *N2* as the gap filler does not take away an argument for the verb.

Before we lay out our theory for the processing of *V+N1+de+N2* in Chinese and its implications for sentence processing in general, some discussion is in order for three issues related to the findings of the present study. First, if the parser initially adopts the right-branching analysis for *V+N1+de+N2* and syntax prohibits the gap to be filled by any noun inside the clause, why would it even evaluate the plausibility of *N2* as a potential filler? In other words, if the parser is blind to the RC analysis, *N2* animacy should never be a contributing factor to the reanalysis. This argument is valid if the parser can maintain only one analysis at a time. In fact, we think the parser simultaneously maintains two (or more) analyses throughout the string and ranks the probability of an analysis at each position (Z. G. Cai, Sturt, & Pickering, 2011; Gibson & Pearlmutter, 2000). This is shown in the results of Experiment 1b, where the RC analysis gradually increases as the construction turns out to be more and more compatible with the RC structure. A ranked parallel processor can look for amount and quality of the cues that support an analysis. In the case of the present study, *N2* animacy is the most important cue for maintaining or changing an analysis (See Hsieh, et al., 2009; Lin & Bever, 2011 for similar arguments). In addition, individual differences seem to vary considerably in estimating the probability of one analysis over the others. In Experiment 1b, the percent RC completion at the end of *V+N1+de+N2* varies from 27% to 79% across participants. Thus, although every participant shows an increase of RC completions from *V+N1+de* to *V+N1+de+N2* (10% – 77%), it remains to be studied how a particular Chinese reader integrates all cues to come to an analysis at *N2*.¹³

Second, if a reanalysis happens at *N2*, why is it not reflected in the reading time of *N2*? But on the other hand, a similar reanalysis that occurs later, after the RC is formed, is reflected in the reading times of *de2* in Experiment 2a and the main clause in Experiment 2b. There seems to be two types of reanalysis, one of which is less costly than the other. This could be related to parallel processing mentioned in the last paragraph. When the parser is still processing the *V+N1+de+N2* string, it may keep some alternative analyses active and consequently, the reanalysis cost is relatively low. But after an analysis is chosen and the semantic relations of the words in the string are established, it may minimize the consideration of other analyses. This could be due to limited working memory capability and a preference to settle on an analysis at the end of a clause. All this can contribute to a higher reanalysis cost when the disambiguation happens outside *V+N1+de+N2*.

Third, is it possible that the two experiments ask for different processing strategies so that the initial right-branching preference in Experiment 1 might not be applicable to real-time sentence comprehension in Experiment 2? Participants can commit to an interpretation (or commit to a structure that will provide an interpretation) when the gap is detected in sentence production (Experiment 1), but the gap can be underspecified in sentence

¹³ We have tried to correlate the reading times of the disambiguation regions in Experiment 2a to the working memory capacity of the participants. We hypothesized that low-span participants might opt to change from an initially preferred right-branching to a RC structure, in order to fill the identified gap and complete the proposition of the subordinate clause earlier. Participants completed the Chinese version of the automated version of the operation span task (Unsworth, Heitz, Schrock, & Engle, 2005) after the reading study. But we found no correlation between the reading times and the memory span of the participants.

comprehension (Experiment 2), i.e., the gap may be interpreted as ‘someone,’ until a certain sentence position when there is more clarity about the gap’s reference. If this was true, then Chinese readers would probably strongly prefer the right-branching analysis at the beginning of *V+NI+de+N2* in sentence comprehension. It is because if gap interpretation is not in the equation, a simpler analysis seems to be the best choice. This is basically consistent with the findings of the completion studies, where the right-branching analysis is found to be strongly preferred at the beginning. Thus, while it remains unknown how much semantic content is added to the gap when the verb is encountered, it is clear that more semantic content, as could be the case in sentence production, does not reduce the right-branching preference. The discussion here nevertheless touches on an outstanding issue about the relationship of sentence production and comprehension. It is possible that the two kinds of tasks engage different language processes and production data may not precisely reflect comprehension preferences. Future studies that use different tasks to investigate the processing of the critical word string would be useful.

Overall, our data point to a few characteristics of gap-filler completion and sentence processing, more generally. A Chinese parser initially follows structural principles to select an analysis for the partial input. Thus, an analysis that provides the most structural economy tends to win over more complex analyses. But as more words are received and more semantic content becomes available, the parser may override an initial analysis in favor of one that can provide the most meaningful output. This hypothesis is compatible with previous studies on Chinese sentence processing that the animacy of the first NP does not have significant effects on parsing, but the animacy of a following NP does (Philipp, Bornkessel-Schlesewsky, Bisang, & Schlewsky, 2008; Wang, Schlewsky, Bickel, & Bornkessel-Schlesewsky, 2009). We illustrate these various processes (parallel parsing, minimizing structural complexity, maximizing interpretation) using the sentences (5c,d), which are repeated below.

(5)	c/d	
		等待 客人 的 朋友/ 答复 已经 很久了。
		wait guest DE friend/ reply already long-time
		“It has been a long time to wait for the guest’s friend/reply.”

A subject gap is posited when the sentence-initial verb is received. At *NI* (*guest*), a structurally simpler right-branching analysis has been adopted while the RC and other analyses are ranked low in preference. When *de* appears, the parser may move the RC preference up the rank because *de* is an essential RC component and the RC parse can facilitate gap-filler completion. However, given the uncertainty of the semantic property of the upcoming *N2* and the substantial structure it needs to build to support the RC parse, the parser is likely to maintain the right-branching structure. Thus, *de* is attached inside the object NP and *NI* is taken as a noun modifier. The crucial structural decision is made when *N2* is encountered. If it is inanimate (*reply*) and thus not a good filler for the subject gap, the right-branching parse persists; *N2* will be taken as the object noun. But if it is animate (*friend*) and thus a good filler, the RC preference will increase considerably. We hypothesize that the structural revision is driven by the interpretation requirement to complete a proposition (in this case, through gap-filler completion).

All this implies that Chinese sentence processing is non-deterministic. The parser follows one analysis initially and maintains alternative analyses for an ambiguous construction; it allows for reanalysis subsequently if an alternative analysis provides a more meaningful partial output. In the case of the present study, the availability of a potential filler for an identified gap is the main driving force for structural revision. This filler noun provides semantic content for the subject gap, and serves the important function of fulfilling the interpretation requirement. Thus, reanalysis is undertaken despite the fact that the current analysis is still legitimate. Although the sentence structures of the present study are quite unique to Chinese, our data show that the human sentence processor is willing to override structural principles when an alternative analysis presents semantic advantage. We propose that this is a general principle that should apply to other languages.

In conclusion, gap-filler processing is a useful tool to study semantic processing. An unfilled gap creates an incomplete proposition for a clause and expectation for a filler, which can change how ambiguity is resolved. In the case of the ambiguous *V+N1+de+N2* construction in Chinese, the initial preference for a right-branching structure may be overridden for gap-filler completion. This supports non-deterministic sentence processing in Chinese, where parsing is a dynamic process with both semantic and syntactic information used incrementally during sentence comprehension.

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Appendix A

Stimuli of Experiments 1 and 2a. Nouns that refer to institutions, e.g., school and company, are considered to be animate nouns. The determiner in parentheses is present only in some conditions of the sentences.

1. (这个)爱护自己的孩子/身体的母亲忍不住哭了。
The mother who cared about her own children/health could not hold back her tears.
2. (这两个)比较医生的病人/技能的院长认为医学院的课程需要改革。
The two presidents who compared the doctors' patients/skills thought that the curriculum of the medical school needed reform.
3. (这个)表扬徐心的同学/作为的老师常常奖励见义勇为的行为。
The teacher who commended XuXin's classmate/conduct often rewarded righteous behaviors.
4. (这个)操纵公司的领导/金融的主席不打算自动辞职。
The chairman who controlled the company's leaders/finance was not planning to resign.
5. (那个)等待客人的朋友/答复的主人很焦急。
The host who waited for the guest's friend/reply was very anxious.
6. (那个)调查朋友的上司/案情的探员下个月退休。
The detective who investigated the friend's superior/case would retire next month.
7. (这个)抵抗人民的政府/意志的独裁者最终被判终身监禁。
The dictator who resisted the people's government/will ultimately received a life sentence.
8. (那个)督促朋友的教练/进展的训练员提出很多有用的建议。
The drillmaster who supervised the friend's coach/progress gave out lots of useful suggestions.
9. (这个)锻炼孩子的哥哥/毅力的教练特别严厉。
The coach who trained the child's brother/ stamina was very stern.
10. (这三个)对抗总统的顾问/政策的积极分子绝对不会退让。

The three activists who opposed the president's advisor/policy would never yield.

11. (这个)反对大国的领导/垄断的自由论者准备筹划下一步抗议行动。

The libertarian who opposed the superpower's leaders/monopoly was organizing the next protest movement.

12. (那个)放弃孩子的姐姐/治疗的父亲觉得自己已经走到穷途末路。

The father who gave up the child's sister/treatment felt that he had reached the dead end.

13. (这个)辅导小亮的朋友/功课的导师今天不来了。

The instructor who tutored XiaoLiang's friend/homework will not come today.

14. (这两个)改变齐琳的室友/人生的舍监得到很多学生的尊敬。

The two wardens who changed QiLin's roommate/philosophy of life were well respected by many fellow students.

15. (这三个)干扰小秦的同伴/工作的流氓被刘大妈赶走了。

The three hoodlums who disturbed XiaoQin's companion/work were chased away by Auntie Liu.

16. (这五个)鼓动刘强的同乡/干劲的年轻人经历过不少挫折。

The five young people who encouraged LiuQiang's townspeople/enthusiasm had gone through many ups and downs.

17. (那三个)号召协会的领袖/参与的工会干事已开始筹划下一步行动。

The three union organizers who appealed to the association's leaders/action had started to organize the next action.

18. (这个)护理小王的姨母/起居的护士很喜欢她的工作。

The nurse who cared for XiaoWang's aunt/daily life loved her work.

19. (这个)怀念故乡的朋友/明月的飘零人每到春节总觉得很孤单。

The drifter who thought about the hometown's friends/bright moon always felt lonely during the lunar New Year.

20. (这个)回忆抗战时期的战友/岁月的连长不禁想起在远方的老朋友。

The company commander who recollected the battle's companions (=companions from the battle)/life inevitably recalled the old friends from afar.

21. (这个)监视敌人的间谍/活动的情报人员离奇死亡。

The intelligent agent who monitored the enemy's spies/activities died a mysterious death.

22. (这个)接近孩子的母亲/心灵的心理医生很了解她的家庭问题。

The psychologist who understood the child's mother/feelings was well-acquainted with her family problems.

23. (这个)考验赵峰的公司/诚意的记者准备写一篇专题报道。

The reporter who probed ZhaoFeng's company/veracity was going to write a special coverage.

24. (那个)控诉总统的内阁/暴行的异见人士被判无期徒刑。

The dissenter who denounced the president's cabinet/atrocity was sentenced to life imprisonment.

25. (那个)理解苏珊的丈夫/用意的朋友不同意这个离婚的决定。

The friend who understood SuShan's husband/intention disagreed with the divorce decision.

26. (这个)联络职员的上司/感情的秘书放假去旅行了。

The secretary who contacted the staff's superiors/affection (=made friendly contact) was off on vacation.

27. (这个)联系总统的秘书/住处的参谋长做了一个果敢的决定。

The chief-of-staff who contacted the president's secretary/residence made a bold decision.

28. (这个)了解政府的密探/动向的翻译员出卖了自己的国家。

The translator who had knowledge of the government's secret agents/plans sold out his own country.

29. (这个)留神小偷的同伴/行径的顾客已知会售货员。

The customer who kept an eye on the thief's companion/tricks had notified the sales clerks.

30. (这两个)留心主席的顾问/变化的同事已知道公司的裁员消息。

The colleague who paid attention to the chairman's consultant/changes had already got the news of the job cuts.

31. (那个)埋怨小王的领导/懒惰的科长对工人的素质有很严格的要求。

The foreman who complained about XiaoWang's boss/inertia had a high demand on workers' aptitude.

32. (这个)明白教授的医生/意思的护士拥有丰富的经验。

The nurse who understood the professor's doctor/intention was very experienced.

33. (这个)顺从老人的女儿/意见的孩子很懂人情。

The child who yielded to the old man's daughter/wishes knew the score.

34. (那个)盘问王五的妻子/秘密的公安把一些文件带走。

The cop who inquired about WangWu's wife/secret took away some documents.

35. (这个)佩服王强的父亲/精神的青年打算参军。

The young man who admired WangQiang's father/spirit was planning to join the army.

36. (这个)批判小张的老师/思想的教育家做了很多有关儿童教育的研究。

The educator who criticized XiaoZhang's teacher/opinions had conducted a lot of studies on child education.

37. (这个)批评老马的班长/错误的导师得不到学生的尊重。

The instructor who criticized LaoMa's class monitor/mistake was not respected by the fellow students.

38. (那两个)评论夏雨的导演/演技的编剧家在演艺界很有名。

The two screenwriters who commented on XiaYu's director/acting skills were famous in performing arts.

39. (这个)敲诈老王的外甥/钱财的女人已经逃之夭夭。

The woman who extorted LaoWang's nephew/money had fled.

40. (这几个)轻视小刘的同学/劳动的小霸王是最不勤奋的一群。

The bullies who belittled XiaoLiu's classmates/labor were the laziest bunch.

41. (那个)算计王强的侄子/房产的小人总归有报应。

The scoundrel who conned WangQiang's nephew/property would be avenged for the crime.

42. (这个)探望父母的朋友/病情的孝顺儿对人总是关怀备至。

The filial son who inquired about the parents' friends/illness was caring.

43. (这几个)挑战将军的敌人/权威的副官在军部的资历不浅。
The adjutants who challenged the general's rival/authority were veterans in the military.
44. (这个)同情法官的秘书/处境的同僚都为她的处境难过。
The colleagues who sympathized with the judge's secretary/situation identified with her plight.
45. (这个)挽救朋友的司机/性命的英雄激励了无数青年人。
The hero who saved the friend's chauffeur/life inspired a lot of young people.
46. (那个)侮辱门童的弟弟/人格的富翁从来看不起穷人。
The moneybags who insulted the doorman's brother/character often looked down on poor people.
47. (这个)相信小王的朋友/话语的姑娘知道自己被骗了。
The woman who believed XiaoWang's friend/words learned that she was cheated on.
48. (这个)想念小李的母亲/歌声的侄女刚给她写了一封信。
The niece who missed XiaoLi's mother/songs just wrote her a letter.

Appendix B

Stimuli of Experiment 2b. Nouns that refer to institutions, e.g., school and company, are considered to be animate nouns. The subject noun in parentheses is present only in some conditions of the sentences.

1. (父母)爱护自己的孩子/身体是应该的。
It is natural for (parents) to take care of their children/health.
2. (院长)比较医生的病人/技能就可以知道哪一个医生好。
It would allow one to learn about the quality of the doctors if (the hospital president) compared the doctors' patients/skills.
3. (许老师)表扬徐心的同学/作为可以使其他同学效法。
It would provide a learning opportunity to other students if (Mr. Xu) commended Xuxin's classmate/conduct.
4. (韩小斌)操纵公司的领导/金融是计划的第一步。

It would be the first step of the plan for (HanXiaobin) to control the company's leaders/finance.

5. (我们)等待客人的朋友/答复已经很久了。

It has been a long time for (us) to wait for the guest's friend/reply.

6. (公安局长)调查朋友的上司/案情不是那么容易。

It would not be easy for (the police chief) to investigate the friend's superior/case.

7. (军队)抵抗人民的政府/意志使这个独裁者被人民唾弃。

It resulted in contempt of the dictator when (the army) resisted people's government/will.

8. (军勇)督促朋友的教练/进展可以令她进步得快一点。

It would make her improve faster if (JunYong) supervised the friend's coach/progress.

9. (名教练)锻炼孩子的哥哥/毅力对他的网球事业很重要。

It would be important to his tennis career if (the famous coach) trained the child's brother/stamina.

10. (他们)对抗总统的顾问/政策对你没好处。

It would not be to your advantage for (them) to oppose the president's advisor/policy.

11. (自由论者)反对大国的领导/垄断是抗议的口号。

The slogan in the protest was that (the libertarians) opposed the superpower's leaders/monopoly.

12. (舅母)放弃孩子的姐姐/治疗令父亲伤心欲绝。

It was disheartening to the father when (the aunt) gave up the child's sister/treatment.

13. (黄老师)辅导小亮的朋友/功课会增加工作量。

It would increase the workload if (Miss Huang) tutored XiaoLiang's friend/homework.

14. (舍监)改变齐琳的室友/人生绝对不容易。

It would not be easy for (the wardens) to change QiLin's roommate/philosophy of life.

15. (艺芳)干扰小秦的同伴/工作是为了报复。

It was for revenge when (YiFang) disturbed XiaoQin's companion/work.

16. (他们)鼓动刘强的同乡/干劲才可以把这项任务完成。

The mission would be accomplished only if (they) encouraged LiuQiang's townspeople/enthusiasm.

17. (温会长)号召协会的领袖/参与可以壮大我们的力量。

It would increase our strength if (President Wen) appealed to the association's leaders/action.

18. (李护士)护理小王的姨母/起居加重了自己的负担。

It increased her burden when (Miss Li) cared for XiaoWang's aunt/daily life.

19. (李春明)怀念故乡的朋友/明月总在夜深。

It was always in the middle of the night when (LiChunMing) thought about the hometown's friends/bright moon.

20. (他们)回忆抗战时期的战友/岁月是聚会的焦点。

It was the focal point of the gathering when (they) recollected the battle's companions (=companions from the battle)/life.

21. (情报人员)监视敌人的间谍/活动是国防部长的主义。

It was the defense minister's idea for (the intelligent agents) to monitor the enemy's spies/activities.

22. (心理学家)接近孩子的母亲/心灵对了解孩子很重要。

It would be important for (the psychologist) to understand the child's mother/feelings.

23. (这个记者)考验赵峰的公司/诚意是报社完成调查的最后一步。

It was the last step in the investigation when (the reporter) probed ZhaoFeng's company/veracity.

24. (异见人士)控诉总统的内阁/暴行演变成一场政治风暴。

It created a political storm when (the dissenter) denounced the president's cabinet/atrocity.

25. (治疗师)理解苏珊的丈夫/用意也未能平息他们的家庭纠纷。
- It would not dissolve the dispute in their family even if (the therapist) understood SuShan's husband/intention.
26. (秘书)联络职员的上司/感情可以增进公司内部沟通。
- It would improve the internal communication of the company if (the secretary) contacted the staff's superiors/affection (=make friendly contact).
27. (他们)联系总统的秘书/住处也不一定给他们一个与总统会面的机会。
- It still might not give them a chance to meet with the president even if (they) contacted the president's secretary/residence.
28. (杜文光)了解政府的密探/动向可能是他妻子离奇失踪的原因之一。
- One of the reasons for his wife's mysterious disappearance could be because (DuWenGuang) had knowledge of the government's secret agents/plans.
29. (我们)留神小偷的同伴/行径使他们不能下手。
- It fouled their plan when (we) kept an eye on the thieves' companion/tricks.
30. (职员)留心主席的顾问/变化就可以知道公司的动向。
- It would allow them to learn about the development of the company if (the workers) paid attention to the chairman's consultant/changes.
31. (他们)埋怨小王的领导/懒惰也帮不了事情。
- It would not help even if (they) complained about XiaoWang's boss/inertia.
32. (你们)明白教授的医生/意思对医学实验有很大的帮助。
- It would help the medical experiment if (you) understood the professor's doctor/intention.
33. (医护人员)顺从老人的女儿/意见可以增进他们和病人的信任。
- It could improve the trust between them and the patient if (the hospital staff) yielded to the old man's daughter/wishes.
34. (公安)盘问王五的妻子/秘密也不能帮助了解事情的真相。
- It would not help unveil the truth of the matter even if (the cop) inquired about WangWu's wife/secret.
35. (王峰)佩服王强的父亲/精神是他鼓励儿子参军的主要原因。

The main reason for him to encourage the son to join the army was because (WangFeng) admired WangQiang's father/spirit.

36. (田校长)批判小张的老师/思想只是推卸责任而已。

It was intended only to shirk his responsibility when (Mr. Tian) criticized XiaoZhang's teacher/opinions.

37. (你)批评老马的班长/错误只会增加他的误会。

It would only increase his misunderstanding if (you) criticized LaoMa's class monitor/mistake.

38. (社交传媒)评论夏雨的导演/演技是这些编剧家的共同话题。

The common topic of these screenwriters was that (the social media) criticized XiaYu's director/acting skills.

39. (流氓)敲诈老王的外甥/钱财是老马的主义。

It was LaoMa's idea to have (the scumbag) extort LaoWang's nephew/money.

40. (他们)轻视小刘的同学/劳动就等于轻视我们。

It was like belittling us when (they) belittled Xiaoliu's classmates/labor.

41. (她)算计王强的侄子/房产引起亲友不满。

It aroused discontent among the relatives when (she) conned WangQiang's nephew/property.

42. (你们)探望父母的朋友/病情会令他们很感动。

It would touch them when (you) inquired about the parents' friends/illness.

43. (副官)挑战将军的敌人/权威引起总司令的不满。

It aroused discontent of the chief commander when (the adjutant) challenged the general's rival/authority.

44. (黄书记)同情法官的秘书/处境也于事无补。

It wouldn't help the matter even if (Mr. Huang) sympathized with the judge's secretary/situation.

45. (王陵骏)挽救朋友的司机/性命令是英勇的行为。

It was a heroic behavior when (WangLingJun) saved the friend's chauffeur/life.

46. (她)侮辱门童的弟弟/人格是为了显示自己的地位。

It was intended to show off her status when (she) insulted the doorman's brother/character.

47. (他)相信小王的朋友/话语就是他的最大的错误。

It was his biggest mistake when (he) believed XiaoWang's friend/words.

48. (她)想念小李的母亲/歌声完全是可以理解的。

It was totally understandable when (she) felt she missed XiaoLi's mother/song.

- Chinese gap-filler completion is used to test syntactic and semantic processes.
- Construction of interest is *Verb+Noun1+de+Noun2* that contains a subject gap.
- Right-branching analysis was found to be initially preferred for the construction.
- The more complex relative clause was adopted if *Noun2* was a good filler.
- Chinese parser will override structural economy to complete a proposition.

Figure 1.

The main clause (left), subject clause (middle), and relative clause (right) structures for the string in (1). (Comp: complementizer; PossP: possessive phrase)

Figure 2. Percents of right-branching and RC completions for the four types of fragments in Experiment 1a. Error bars represent 95% confidence intervals.

Figure 3. Percents of right-branching and RC completions for the four types of fragments in Experiment 1b. Error bars represent 95% confidence intervals.

Figure 4.

The two analyses, (B1) and (B2), for the sentence in (4c) when the *N2* noun *friend* is received. If the right-branching analysis (B2) is still assumed, *friend* would be attached inside the object NP as the head noun. Then when *de2* and *host* subsequently appear, the whole segment is tucked inside a RC structure with *host* as the head noun (C). This operation is the same as that for the sentence in (4d), where *reply* is the *N2*. But if a RC structure (B1) is formed when *friend* is received, the subsequent appearance of *de2* and *host* would force a reanalysis with *friend* to be attached inside the object NP (B2).

Figure 5.

Two alternative analyses for (4c). Left: *host* is taken as the object noun of the verb *waited*. Right: *friend de host* is taken as the NP modified by a RC, with either *friend* or *host* as the filler for the subject gap.

Figure 6.

Mean reading times of the $N1+de+N2+de+N3+[N3+1]$ segment in the target sentences in Experiment 2a. The asterisk indicates a significant difference in the reading times among the 4 conditions was found at that position. Error bars are omitted for clarity.

Figure 7.

Mean reading times of each word in the target sentences (excluding the overt subject in two conditions) in Experiment 2b. *MC* stands for main clause. The asterisk indicates a significant difference in the reading times among the 4 conditions was found at that position. No statistical analyses were performed on words after *MC4*. Error bars are omitted for clarity.

Figure 8.

Left: The reading times for a word averaged across all words in the main clause; Right: The reading times of the sentence-final word. Error bars represent 95% confidence intervals.

Table 1

Accuracy rates and reaction times to the comprehension questions of the target sentences in Experiments 2a and 2b.

	Experiment 2a				Experiment 2b			
	[+det,+an]	[+det,-an]	[-det,+an]	[-det,-an]	[+subj,+an]	[+subj,-an]	[-subj,+an]	[-subj,-an]
Accuracy rate (%)	83	86	86	87	87	93	81	93
Reaction time (ms)	3244	2974	3762	2945	3085	3077	3603	2879