

## Chapter 12

# Animacy and the Resolution of Temporary Ambiguity in Relative Clause Comprehension in Mandarin

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Language comprehension does not always proceed completely smoothly. One source of difficulty is structural ambiguity, which is quite prevalent in language. Even in the absence of ambiguity, though, some structures can be harder to process than others. Relative clause constructions have proven useful in shedding light on how comprehenders deal with both of these sources of difficulty. The two kinds of relative clause construction in English can be illustrated by the following examples (1a) and (1b)

- (1) a. Object relative clause  
The reporter who the senator attacked   t   admitted the error.
- b. Subject relative clause  
The reporter who   t   attacked the senator admitted the error.

Relative clauses are one type of wh-construction where relativizers such as “who” or “which” appear in designated positions, leaving a gap or trace (marked as *t* in the sentences above) in their original position. These two types of relative clauses are distinguished by the role that the head noun (“the reporter”) plays in the relative clause. In (1b), the reporter serves as the doer of the action “attacked” in the relative clause, while in (1a), in contrast, the reporter is the object of the action “attacked”. Based on the head noun’s function within the relative clauses, (1b) is called a subject relative clause while (1a) is called an object relative clause. The main clauses and the subject role of the relative clause head noun in the main clause are identical in the two sentences.

Traditionally, relativizers such as “who” have been called “fillers” since they can be mapped to fill gaps that are posited in the canonical position for noun phrases with their function. The relationship between filler and gap can be

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MacDonald & Christiansen, 2002; Real & Christiansen, 2007; Tabor, Juliano, & Tanenhaus, 1997). According to this hypothesis, the word order that is most common in a language will be the easiest for people to process. Consider the English relative clauses below:

(4) a. Subject relative clause

The reporter who attacked the senator admitted the error.

S                      V                      O

b. Object relative clause

The reporter who the senator attacked admitted the error.

O                      S                      V

Ignoring the relativizer “who”, subject relative clauses have SVO word order, which is canonical in English, while object relative clauses have the less frequent OSV word order. Thus, subject relatives should be easier for English speakers to understand, which they are.

Note that all of the factors described so far are a consequence of word order, since that is what determines Linear and Structural Distance. Since canonical word order varies across languages, these kinds of accounts would make different predictions for different languages. In contrast, there are other accounts whose predictions do not differ across languages. One is the noun phrase Accessibility Hierarchy proposed by Keenan and Comrie (1977). It aims to provide a single generalization across human languages. The accessibility to relative clause formation of certain noun phrases is given as follows (5):

(5) Subject > Direct Object > Indirect Object > Oblique Object > GEN > Object of Comparison

Being higher on the hierarchy means that there are more languages that can relativize on this grammatical function. For example, all languages can relativize on subjects but fewer languages can relativize on both subjects and direct objects. If a language can relativize on indirect objects, it can also relativize on direct objects and subjects. While English allows relativization of all grammatical functions (Fox, 1987), some other languages such as Mandarin can relativize only on some of them. The Accessibility Hierarchy puts subject highest in the hierarchy for all languages, so this account predicts that subject relative clauses should be universally easier than object relative clauses, regardless of other properties shown in different languages.

Another explanation (MacWhinney & Pleh, 1988) hypothesizes that people are oriented to the subject of a clause by default because the subject is what the clause is about and shifting perspective to another functional role in the sentence will be harder than maintaining the subject’s perspective. Subject relative clauses modifying the main clause subject will be easiest since they require no shifting of perspective. In object relative clauses, however, people have to shift

their perspective between the subject of the main clause (“reporter”) and the subject of the relative clause (“senator”) and then back to the main clause subject. In contrast, for relative clauses modifying main clause objects, both subject and object relatives require a single shift. For object relatives modifying main clause objects, there must be a single shift from the object of the main clause to the subject of relative clause. For subject relatives modifying main clause objects, a single shift is also required to shift from object of the main clause to subject of the relative clause. To summarize, this account predicts that subject relatives modifying main clause subjects should be easiest, subject and object relatives modifying main clause objects should both be about the same amount harder and object relatives modifying main clause subjects should be hardest. This ranking of difficulty should be consistent across languages, according to the Perspective Shift account.

The accounts described so far do not stress the importance of the processing demands of the moment-by-moment integration of incoming words. Other recent work has emphasized the representations that comprehenders construct based on the moment-by-moment integration of different kinds of information (e.g., Altmann & Steedman, 1988; Gibson & Pearlmuter, 1998). Gibson (1998, 2000) proposed the Dependency Locality Theory, which has two major sources of processing cost, called integration cost and memory cost, both of which are related to locality and working memory demands. Integration cost refers to the effort involved in linking a new incoming word into the existing structure. There is also integration cost at the discourse level, where one energy unit is consumed for each new discourse referent. For structural integration, it is cost-free to integrate a VP with an NP when there are no intervening items between them. If there are intervening words, one energy unit will be consumed for each intervening noun and verb until integration can take place. In sum, Dependency Locality Theory provides an account for why object relative clauses are harder in English in terms of the total amount of energy consumed.

Each of the accounts described above tries to explain an asymmetry in the difficulty of subject and object relative clauses in English. It is impossible to tease them apart in English because they all predict object relative clauses to be harder. However, some of these accounts make opposite predictions about relative clauses in other languages. One of the controversial issues in current psycholinguistic research is whether object relative clauses are universally more difficult than subject relative clauses. So far, most research in other languages has found object relative clauses to be harder than subject relative clauses, just as in English (Dutch: Mak, Vonk, & Schriefers, 2002; French: Cohen & Mehler, 1996; German: Schriefers, Friederici, & Kuhn, 1995; Japanese: Miyamoto & Nakamura, 2003; Ueno & Garnsey, 2008; Korean: Kwon, Polinsky, & Kluender, 2006). However, research on Mandarin relative clauses has yielded a different pattern of results. Mandarin is different from Indo-European languages in several important ways: it has no case marking, inflection, or agreement and allows pro-drop, meaning that arguments that would be pronominalized in English can sometimes be omitted completely in Mandarin. Another important

difference is that the head noun occurs after the relative clause in Mandarin, rather than before as it does in English. Hsiao and Gibson (2003) predicted that Mandarin speakers should find subject relatives harder than object relatives and found reading time evidence supporting that prediction. However, their findings have been disputed and Lin (2006; Lin & Bever, this volume) and Kuo and Vasishth (2007) have both found Mandarin object relative clauses to be more difficult, consistent with findings from other languages. In the following section, the construction of relative clauses in Mandarin will be introduced and discussed in more detail.

## 12.1 Mandarin Relative Clauses

Relative clauses in Mandarin use the word “DE”, which functions as a relativizer but also has several other functions. In relative clauses, DE functions like the relative pronoun in English and it is used with both animate and inanimate head nouns. Although English and Mandarin both have default SVO basic word order, in Mandarin relative clauses the head noun occurs at the end of the clause, unlike English, where the head occurs at the beginning of the relative clause. Mandarin relative clauses are thus said to be “head-final”. The following examples illustrate the construction of Mandarin relative clauses:

### (6) a. Mandarin object relative clause

人們	完全	不	相信	[伯爵	批評	<u>t</u>	的	公主]。
people	definitely	not	believe	[count	criticize	<u>t</u>	DE	princess]
				S	V			O

(People definitely do not believe [the princess who(m) the count criticized].)

### b. Mandarin subject relative clause

人們	完全	不	相信	[ <u>t</u>	批評	伯爵	的	公主]。
people	definitely	not	believe	[ <u>t</u>	criticize	Count	DE	princess]
					V	O		S

(People definitely do not believe [the princess who criticized the count].)

DE serves as the relativizer in the relative clause and a trace (marked above as *t*) is posited at the position where the head noun would be if it were not moved to the end of the relative clause. For Mandarin object relative clauses, the trace position is between the relative clause verb and DE, while for subject relative clauses, the trace is at the beginning of the clause. As illustrated in (6), an important difference between English and Mandarin is that in Mandarin it is object relative clauses that have SVO word order, which is the canonical word order in Mandarin. Subject relative clauses, on the other hand, begin with a verb and have a VOS word order, which is non-canonical and thus less frequent.

Therefore Mandarin and English differ in which kind of relative clause has default word order.

Given Mandarin's default SVO order, it is not typical for clauses to begin with a verb. However, Mandarin is also a pro-drop language, which means that subject nouns are often dropped, so sentences beginning with a verb are not so uncommon. In fact, one of the most common expressions that Mandarin speakers use to greet each other is: "Eaten yet?" as (7) below:

- (7) 吃 飽 了 嗎 ?  
 Eat full asp Q  
 (Have you eaten yet?)

Since there is no case marking or inflection on the verb in Mandarin, the example in (7) begins with an ordinary verb. Sentences containing "before" or "after" clauses in Mandarin can also begin with verbs. For example, "eat" comes before "before" and starts the clause with a verb in the Mandarin translation of "Before getting full". Thus, when a Mandarin sentence begins with a verb, it does not necessarily imply that there is a relative clause, though that is certainly one of the possibilities. It is not until DE appears that a relative clause becomes close to a certainty.

### ***12.1.1 Predictions About Mandarin Relative Clauses***

The theoretical accounts described above provided accounts for the asymmetry in the difficulty of subject and object relative clauses in English. Researchers such as Just and Carpenter (1992) and Keenan and Comrie (1977) have argued that object relative clauses are universally more difficult than subject relative clauses, for reasons outlined earlier. So far, several cross-linguistic studies have provided evidence consistent with this claim (Dutch: Mak et al., 2002; French: Cohen & Mehler, 1996; German: Schriefers et al., 1995; Japanese: Miyamoto & Nakamura, 2003; Ueno & Garnsey, 2008; Korean: Kwon et al., 2006) but results so far have been inconsistent for Mandarin relative clauses. In the following sections, the predictions of the different accounts of relative clause processing difficulty for Mandarin relative clauses will be described first and then the findings of recent studies on Mandarin relative clauses will be reviewed.

According to the Accessibility Hierarchy account (Keenan & Comrie, 1977), subject relatives should be easier than object relatives in all languages. The Perspective Shift account (MacWhinney & Pleh, 1988) also predicts that Mandarin subject relatives should be easier than object relatives. Mandarin object relative clauses begin with a noun and since first nouns are most likely to be subjects, comprehenders should take its perspective. However, when DE appears, people realize that the first noun is part of an object relative clause and

that another upcoming noun will be the main clause subject. Therefore they will have to shift their perspective. Since subject relative clauses begin with a verb, the predictions of the Perspective Shift account are less clear. If people are still oriented to subjects by default even when they appear to be missing, then subject relative clauses in Mandarin require no Perspective Shift since the subject perspective that is assumed at the beginning of the sentence matches with the role that the head noun plays in the relative clause. Since object relative clauses require a shift while subject relative clauses require none, the Perspective Shift account predicts that subject relative clauses should be easier than object relative clauses in Mandarin.

The other accounts of relative clause processing asymmetry make different predictions for Mandarin than they do for English. The Word Order Frequency account (MacDonald & Christiansen, 2002) predicts that it is object relatives that should be easier in Mandarin because they have the canonical and thus more frequent SVO word order.

Gibson’s Dependency Locality Theory (Gibson, 1998, 2000) also predicts that object relatives should be easier in Mandarin. Object relatives incur no integration cost because there are no words intervening between the trace and the relative marker DE, while subject relatives consume two energy units since there are two intervening words.

(8) a. Mandarin object relative clause

	councilman	interrogate	<i>t</i>	DE	official
Discourse integration	1	1	0	0	1
Structural integration	0	0	0	0	0
Total	1	1	0	0	1

b. Mandarin subject relative clause

	<i>t</i>	interrogate	councilman	DE	official
Discourse integration	0	1	1	0	1
Structural integration	0	0	0	2	0
Total	0	1	1	2	1

This analysis follows from Hsiao and Gibson’s (2003) argument that comprehenders would treat (8b) as a subject relative clause from the start, since no subject noun precedes the verb. A trace is therefore posited at the beginning of the subject relative and the distance between that trace and its head noun filler increases the integration cost at the head noun. This analysis could be disputed, since sentences beginning with verbs could turn out to be other kinds of constructions, as described earlier. However, Grodner, Gibson, and Tunstall (2002) argued that Dependency Locality Theory predicts Mandarin subject relative

clauses should be harder than object relative clauses even without this assumption because Mandarin subject relative clauses require some reanalysis when the initial analysis turns out to be incorrect, which will be more costly. (Storage costs are also predicted to be greater for Mandarin subject relatives but we will not work through those predictions in detail here.)

Finally, distance accounts also make predictions about Mandarin relative clause processing asymmetry but their accounts are also based on the assumption that sentences beginning with verbs are treated as subject relative clauses from the start. Example (9) below shows that there is a shorter linear distance between gap and filler in object relative clauses than subject relative clauses in Mandarin, leading to the prediction that object relative clauses should be easier to process than subject relative clauses.

(9) a. Mandarin object relative clause

參議員      攻擊 *t* 的記者  
councilman      attack *t* DE reporter



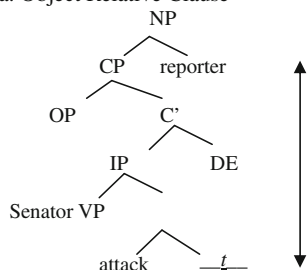
b. Mandarin subject relative clause

*t* 攻擊 參議員      的 記者  
*t* attack councilman      DE reporter

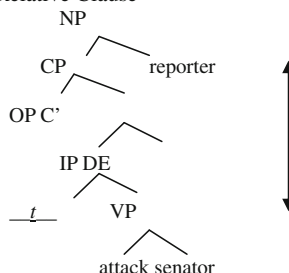


Recall that for English, Linear and Structural Distance both predicted that subject relatives should be easier. Interestingly, in Mandarin the linear and Structural Distance accounts make opposite predictions. As example (10) below shows, Structural Distance is greater in object relative clauses in Mandarin, which should make them harder.

(10) a. Object Relative Clause



b. Subject Relative Clause



For English, all of the accounts agree in predicting that object relative clauses should be more difficult. It seems likely that each of these accounts captures some aspect of the reasons for differences in processing difficulty between subject and object relatives, so since they all agree, differences should be quite robust in English and they are. However, in a language like Mandarin, where some factors point in one direction and others in the opposite direction, processing asymmetries might be expected to be smaller and that may account



for the inconsistent results obtained in studies so far, which are described in the next section. In summary, the Accessibility Hierarchy, Perspective Shift and Structural Distance accounts all predict that object relatives should be harder in Mandarin, while the Word Order Frequency, Dependency Locality Theory and Linear Distance accounts all predict that it is subject relatives that should be harder in Mandarin.

### ***12.1.2 Previous Studies of Mandarin Relative Clause Processing***

There have been several studies of Mandarin relative clause processing, which have yielded inconsistent results. Hsiao and Gibson's (2003) study was the first on Mandarin relative clauses and employed a self-paced reading time paradigm. Their stimuli included both singly-embedded and doubly-embedded relative clauses and reading time differences were robust only in the doubly-embedded versions. The doubly-embedded sentences were quite difficult to understand, so it has been argued that the results for those may not reflect normal sentence processing procedures (e.g., Christianson, Hollingworth, Halliwell, & Ferreira, 2001). If comprehenders stop trying to figure things out at some point, results for doubly-embedded relative clauses may not be the best indicator of the relative difficulty of subject and object relative clauses more generally. On the other hand, if the relative clause processing asymmetry is smaller in Mandarin than it is in English, it may be observable only when it is exacerbated by some degree of added difficulty in the sentences.

For sentences with singly-embedded relative clauses, the only position at which there was a reliable difference in Hsiao and Gibson's study was the second word in the sentence. In subject relative clauses, this word was a noun that followed a sentence-initial verb. Longer reading times on this noun might reflect the atypicality of the sentence beginning with a verb, spilling over onto the next word. There is also more ambiguity about how the sentence will continue when the first word is a verb, which could also increase reading times. Thus longer times for subject relatives at the second word may not have been due specifically to relative clause processing.

Lin (2006; Lin & Bever, this volume) criticized Hsiao and Gibson's stimuli because some verbs were used in multiple items and some constructions involved negation in the relative clause region, which could complicate matters. Lin modified the stimuli to remove these objections and also added conditions with relative clauses modifying the main clause object, in addition to the conditions used by Hsiao and Gibson where the relative modified the main clause subject. However, Lin's stimuli were not without their own problems. Some verbs were still used more than once and a verb in one sentence set did not sound natural. For the sentences with relative clauses modifying the main clause subject, Lin found no reliable differences in reading times at any word. For the sentences with relative clauses modifying the main clause object, there were reliable differences

only on the final two words in the relative clauses, i.e., DE and the head noun. At these two positions, it was object relative clauses that were read more slowly. Kuo and Vasishth (2007) also used Hsiao and Gibson's materials and added new materials using either determiners or "bei", a passivization marker. Like Lin, they did not replicate Hsiao and Gibson's results even for the sentences taken from their study but instead found Mandarin object relatives to be harder. Yang, Johnson, and Gordon (2008) conducted two reading time studies of singly-embedded relative clauses using self-paced reading and eye-tracking and found mixed results. At some sentence positions it was subject relatives that were read more slowly while at others it was object relatives. The direction of the difference on the head noun itself differed depending on whether the relative clause modified the main clause subject (subject relative slower) or main clause object (object relative slower). The results in the eye-tracking study were even less clear.

Several other recent studies of Mandarin relative clause processing have either found subject relatives to be harder or found no difference. Hsu and Chen (2007) found subject relatives to be harder but only when sentences were made difficult by increasing the linear distance between gap and filler. When that distance was short, there were no reliable differences. Chen, Ning, Bi and Dunlap (2008) also found subject relatives to be harder but only for readers who tested low on a working memory span measure and thus presumably had more difficulty processing the sentences. Wu and Gibson (2008) found subject relative clauses to be harder when they were embedded in discourse contexts that made relative clause structures especially likely in the target sentences. Interestingly, the size of the effect was much larger in Wu and Gibson study than in any of the other previous studies with singly-embedded relative clauses. They argued that this was because using context to make relative clauses highly likely removed obscuring effects due to ambiguity about whether a sentence had a relative clause or some other structure. Lin and Bever (this volume) also argue that context and other kinds of cues that remove or mitigate temporary ambiguity about whether the sentence contains a relative clause can influence the relative difficulty of subject and object relatives. (See also Hsu & Chen, 2007; Hsu, Hurewitz, & Phillips, 2006; Hsu, Phillips, & Yoshida, 2005; Wu, Haskell, & Andersen, 2006; Yoshida, Aoshima, & Phillips, 2004 for studies investigating how certain sentence-internal cues and/or discourse context can help signal the likely presence of a relative clause in Mandarin or Japanese and how and when such information influences relative clause processing.)

A few studies have used event-related brain potentials (ERPs) to investigate relative clause processing in head-final languages, including Japanese (Ueno & Garnsey, 2008), Korean (Kwon et al., 2006), Mandarin (Packard, Ye, & Zhou, this volume) and Basque (Carreiras, Duñabeitia, Vergara, Zieza, & Laka, 2007). In these studies, it was hypothesized that whichever kind of relative clause was less expected and/or more difficult to process should lead to larger P600s in the ERP waveforms, since P600 is associated with revision and with integration

difficulty (e.g., Kaan, Harris, Gibson, & Holcomb, 2000). Packard et al. (this volume) found larger P600s for subject relatives than for object relatives, though the word on which these effects emerged differed depending on whether the relative modified the matrix clause subject or object. (They argued that the effect emerged at different positions because of differences in when the selectional restrictions of the relative clause verb could be satisfied.) Most importantly, it was subject relatives that consistently elicited larger P600s, leading Packard and colleagues to argue that subject relatives are more difficult in Mandarin. Basque is another language that has head-final relative clauses but it differs from Mandarin in that its default word order is also head-final (SOV). Carreiras et al. (2007) took advantage of ambiguous case and number morphology to construct Basque sentences with relative clauses that were fully ambiguous as to whether they were subject or object relatives until the main clause verb disambiguated them. In two reading time studies, subject relatives were read more slowly than object relatives at the disambiguating words and in an ERP study, subject relatives elicited more P600-like positivity at the disambiguation, suggesting that readers preferred the object relative interpretation up until that point. Japanese and Korean are both like Basque in being generally head-final but without Basque's morphology. ERP studies of Japanese (Ueno & Garnsey, 2008) and Korean (Kwon et al., 2006) have found evidence for a preference for subject relatives, in contrast with the results for Mandarin and Basque.

Another approach to investigating relative clauses in Mandarin has been to examine text corpora to determine which kinds of relatives occur more frequently (Hsiao & Gibson, 2003; Pu, 2007; Wu, Kaiser, & Andersen, this volume), on the assumption that structures that are easier to process should occur more often (Hawkins, 2004). Probably because different text corpora were used in the different studies, there are some inconsistencies in the results. Hsiao and Gibson (2003) found more object relatives than subject relatives in their corpus study but Pu (2007) and Wu et al. (this volume) both found the reverse, i.e., more subject relatives than object relatives. Beyond these major findings about the overall frequency of subject and object relatives, there were also interesting differences depending on the animacy of the head noun and on whether the relative clause modified the matrix subject or matrix object, which we will return to in the introduction of Experiment 2 and in the discussion of our results. There were also some minor differences between Pu's and Wu et al.'s results, which they attributed to differences in the genre of the texts included in the corpora. For now, however, the most important point is that both Pu and Wu et al. argued that the greater frequency of subject relatives in Mandarin suggests that they should be easier to process than object relatives.

The previous experimental studies of Mandarin have used relatively small numbers of stimuli. Given that differences between subject and object relatives seem likely to be smaller in Mandarin than in English because different relevant factors conflict for Mandarin, it seems important to use a larger set of stimuli in order to have a better chance to detect small effects.

### 12.1.3 Topicalization and Dropping the Head Noun in Mandarin Relative Clauses

In Mandarin, it is possible to topicalize the main clause object by moving it to the beginning of the sentence. An example of this construction in English would be: “That guy, I really hate.” Such topicalizations are relatively rare in English but they are considerably more common in Mandarin (Liu, 2005). Examples of object and subject relatives modifying a main clause object are shown below in (11) and topicalized versions of them are shown in (12).

- (11) a. Mandarin object relative clause modifying main clause object

記者 已經 開始 詳細 報導<sup>1</sup> [議員 質詢 的 官員]。  
Reporter already begin detail report [councilman interrogate DE official]  
(Reporters have already begun to report in detail about [the official who the councilman interrogated].)

- b. Mandarin subject relative clause modifying main clause object

記者 已經 開始 詳細 報導 [質詢 議員 的 官員]。  
Reporter already begin detail report [interrogate councilman DE official]  
(Reporters have already begun to report in detail about [the official who interrogated the councilman].)

- (12) a. Mandarin object relative clause modifying topicalized main clause object

[議員 質詢 的 官員] 記者 已經 開始 詳細 報導。  
[Councilman interrogate DE official] reporter already begin detail report  
(About [the official who the councilman interrogated], reporters have already begun to report in detail.)

- b. Mandarin subject relative clause modifying topicalized main clause object

[質詢 議員 的 官員] 記者 已經 開始 詳細 報導  
[Interrogate councilman DE official] reporter already begin detail report  
(About [the official who interrogated the councilman], reporters have already begun to report in detail.)

Notice that in the topicalized examples in (12), because the relative clause is head-final and the main clause is subject-first, the head noun “official” immediately precedes the main clause subject noun “reporter”. The same is not true for the English translation, since in English the head noun precedes the relative clause. This is a point we will return to shortly but first one more property of Mandarin relative clauses must be introduced.

A final interesting property of Mandarin relative clauses is that the head noun can be omitted, especially when it is recoverable from context (Chu & Chi, 1999). For example, the head noun underlined in example (13) can be omitted without causing any obvious difficulties in comprehension. DE remains in its normal position when the head noun following it is dropped.

<sup>1</sup> Although the word “report” in the translation can be used as either a noun or a verb in English, the equivalent word used in the Mandarin sentences can only be a verb. This was true across the materials used in our studies.

(13)

叫 [賣 菜 的 人] 明天 再 來。  
 Ask [sell vegetable DE person] tomorrow again come  
 (Ask the person who sells vegetable to come again tomorrow.)

Now we return to the point raised earlier about the adjacency of the relative clause head noun and the main clause subject noun in topicalized Mandarin sentences (see example 12). When a main clause object is modified by a relative clause and is topicalized, then when the head noun of the relative is dropped, the main clause subject noun immediately follows DE (see example 14 below, where the examples in 12 above are repeated with the head noun omitted.) That leads to temporary ambiguity. On one possible interpretation, “reporter” is the head of the relative, as in “The reporter who interrogated the councilman...” On another possible interpretation (i.e., the one that ultimately turns out to be correct in our materials), the relative clause head is unexpressed and “reporter” is the subject of the subsequent main clause, as in “About the interrogation of the councilman (by someone unspecified), the reporter...” When readers pursue the first interpretation, they are forced to revise it when the obligatorily transitive Mandarin verb “report” is not followed by an object. Note that it is the use of obligatorily transitive Mandarin verbs like “report”<sup>2</sup> that makes it impossible to treat the main clause subject as also being the relative clause head noun. Since “report” requires a direct object and the main clause role of the only available noun is subject, the relative clause must have a missing head noun that serves as the main clause object. It was the possibility of creating this temporary ambiguity that was our main reason for using sentences with topicalized main clause objects, so that properties of the main clause subject nouns could be manipulated to determine how the temporary ambiguity is resolved.

- (14) a. Mandarin object relative clause modifying topicalized main clause object, with head noun omitted

[議員 質詢 的 \_\_\_\_] 記者 已經 開始 詳細 報導。  
 [Councilman interrogate DE \_\_\_\_] reporter already begin detailed report  
 (About the person who the councilman interrogated, reporters have already begun to report in detail.)

- b. Mandarin subject relative clause modifying topicalized main clause object, with head noun omitted

[質詢 質詢 的 \_\_\_\_] 記者 已經 開始 詳細 報導。  
 [Interrogate councilman DE \_\_\_\_] reporter already begin detailed report  
 (About the person who interrogated the councilman, reporters have already begun to report in detail.)

It is important to note that topicalizing a main-clause-object-modifying relative does not change its Linear or Structural Distance properties, nor in fact does it change the direction of the predictions of any of the accounts of

<sup>2</sup> Although the verb usage of “report” is only optionally transitive in English, the equivalent verb in Mandarin is obligatorily transitive. This was true across the materials used in our studies.

relative clause processing difficulty. For example, the tables in (15) below show that Gibson’s Dependency Locality Theory predicts that object relatives should be easier in Mandarin even when they are topicalized.

(15) a. Topicalized main-clause-object-modifying object relative clause in Mandarin

	councilman	interrogate	$t_1$	DE	official	reporter	begin	report	$t_2$
Discourse integration	1	1		0	1	1	1	1	
Structural integration	0	0		0	0	0	0	3	
Memory units	2	1		2	1	2	1	1	
Total	3	2		2	2	3	2	5	

b. Topicalized main-clause-object-modifying subject relative clause in Mandarin

	$t_1$	interrogate	councilman	DE	official	reporter	begin	report	$t_2$
Discourse integration		1	1	0	1	1	1	1	
Structural integration		0	0	2	0	0	0	3	
Memory units		4	3	3	1	2	1	1	
Total		5	4	5	2	3	2	5	

12.2 Experiment 1

The first goal of Experiment 1 was to re-examine asymmetries in processing difficulty for Mandarin relative clauses and the second goal was to investigate ambiguity resolution in relative clauses with dropped heads. The experimental stimuli contained singly-embedded subject and object relative clauses, modifying a topicalized main clause object noun.

12.2.1 Using Topicalization and Head Dropping in the Experiment

Our examples include topicalized object-modifying subject and object relative clauses in Mandarin with and without head nouns, as illustrated below in (16):

(16) a. Mandarin object relative clause modifying topicalized main clause object with head noun present

[議員 質詢 的 官員] 記者 已經 開始 詳細 報導。  
[Councilman interrogate DE official] reporter already begin detail report  
(About [the official who the councilman interrogated], reporters have already begun to report in detail.)

b. Mandarin object relative clause modifying topicalized main clause object with head noun omitted

[議員 質詢 的 \_\_\_\_] 記者 已經 開始 詳細 報導。  
[Councilman interrogate DE \_\_\_\_] reporter already begin detail report  
(About [the person who the councilman interrogated], reporters have already begun to report in detail.)

- c. Mandarin subject relative clause modifying topicalized main clause object with head noun present  
 [質詢 議員 的 官員] 記者 已經 開始 詳細 報導。  
 [Interrogate councilman DE official] reporter already begin detail report  
 (About [the official who interrogated the councilman], reporters have already begun to report in detail.)
- d. Mandarin subject relative clause modifying topicalized main clause object with head noun omitted  
 [質詢 議員 的 \_\_\_\_] 記者 已經 開始 詳細 報導。  
 [Interrogate councilman DE \_\_\_\_] reporter already begin detail report  
 (About [the person who interrogated the councilman], reporters have already begun to report in detail.)

In speech, sentences with topicalized object phrases such as these would probably have some prosodic marking of the clause boundary following the relative clause, realized on and after the head noun when it is present, or on DE when there is no head noun. (We know of no systematic observations about this, however.) In written Mandarin, though, it is optional whether to put a comma after the topicalized relative clause.

### 12.2.2 *Materials, Design and Procedure*

Two experiments were conducted using a word-by-word self-paced reading paradigm with each word appearing centrally on the screen. In each experiment, there were 80 sets of sentences with four versions in each set, namely, subject and object relative clauses, each with and without a head noun present, as illustrated in example (16) above. Most words consisted of two characters but a few had three or four characters. In addition, there were 60 fillers, which were created using other functions of DE in Mandarin to try to distract participants from the relative clause manipulations. For example, DE is used with adjectives such as “beautiful (“piao liang de”, 漂亮的)” and can also be used to mean “during (“de shi hou”, 的時候)”. Four lists were created out of 80 sets of stimuli using a Latin Square design. Each participant saw only one list, which contained 140 sentences, including the 80 experimental stimuli and 60 fillers. The two characters of words such as “老師 (“lao shi”, teacher)” were presented together. The period in Mandarin “。” was presented separately at the end of each sentence. Subjects controlled their own reading pace by pressing the space bar. The session began with instructions and three practice trials. Yes/no comprehension questions were asked at the end of approximately one quarter of the experimental stimuli. The whole experiment took less than 30 min.

Across the 80 sets of stimuli, each relative clause was transitive and thus included both a subject and an object, and nouns filling both roles were present in the (a) and (c) versions of each sentence set but whichever of those nouns was the head of the relative was dropped in the (b) and (d) versions. As described



above, after topicalizing the object of the main clause, the head noun of the relative clause and the main clause subject noun were adjacent. In Experiment 1, these two nouns were always both animate so that when the head noun was missing, the matrix subject noun could plausibly be interpreted initially as the head noun in conditions with the head noun omitted. In addition, in order for both the subject relatives and object relatives to be felicitous, the other noun involved in the relative clause (e.g., “councilman” in example 16 above) also had to be animate, since the relative clause verbs were chosen to require both their subjects and objects to be animate. Making all three of these nouns animate makes our sentences somewhat atypical for sentences containing relative clauses, since corpus studies have found that it is rare for both nouns in a relative clause to be animate (Mak, et al., 2002; Pu, 2007; Wu et al., this volume). It seems likely that this would contribute to making our sentences generally harder to understand, which is a point we will return to later.

Since the materials were constructed so that the same animate head noun could be felicitous in both subject and object relatives, a plausibility norming study was conducted to insure that the head noun was approximately equally plausible in both roles, given the verb and the other noun in the relative. Forty-two native Mandarin speakers who did not participate in the reading time studies were asked to rate the plausibility of the following types of sentences.

(17) The councilman interrogates the official.

(18) The official interrogates the councilman.

Sentences like (17) and (18) were both rated as highly acceptable, though sentences like (17), in which the head noun plays the subject role, as it does in our subject relatives, were rated as slightly more plausible (5.74 vs 5.46, on a 7-point scale, with 1 meaning unacceptable and 7 meaning very natural). Thus, plausibility slightly favored the subject relatives in our materials, so any effect of this small difference in plausibility should facilitate subject relative clause processing.

Care was taken in creating the stimuli to avoid an unlikely but possible problem with the two-noun sequences in the sentences with head noun present. Noun-noun compounds are fairly common in Mandarin, so to prevent readers from treating the two sequentially presented nouns as a compound, rather than as two distinct noun phrases, nouns that could not plausibly combine to form compounds were used, according to the first author’s intuition. In addition, across all of the stimuli, there were compound nouns in only two sentences (one experimental item and one distracter). In both cases, the two components of the compound were presented together. Finally, interpreting the two-word sequences as compounds was unlikely because four-character words are rare, even among compounds. Thus the stimuli and the experimental setting discouraged readers from trying to combine nouns presented sequentially into compounds.



The experiment was conducted in Taiwan at National Taiwan Normal University where most of the 48 subjects were recruited. All were native speakers of Mandarin and most were either college students or held college degrees (approximate mean age 21). Although most spoke English as a foreign language, they all used Mandarin as their primary language in daily communication. At the end of the experiment, subjects were paid a small sum for participation.

### 12.2.3 Results

The yes/no comprehension questions were answered correctly 88% of the time across subjects. An error was discovered in one of the test sentences, so that item was omitted from all analyses. No subjects were dropped from the analyses.

The experimental items varied in both total number of words and in the position within the sentence of certain critical words. For example, in 44 of the 80 experimental items there was an adverb, quantifier, or auxiliary verb of some sort intervening between the main clause subject noun and the main clause verb (e.g., “already” in example (16) above), while in the other 36 items there was not. Two different approaches to handling this kind of variation were taken in the data analyses. In one approach, the reading time for a word that was both the word immediately following the main clause subject noun and the main clause verb contributed to means calculated for both of those sentence positions. This resulted in equal numbers of trials contributing to means for each position. The logic was that this word conveyed important information both because it was a non-noun immediately following the main clause subject and also because it was a verb. In the other approach, if the word immediately following the main clause subject noun was a verb, it contributed only to the means for the verb position and not to the means for the word immediately following the subject noun, with the result that different numbers of trials contributed to the means at different sentence positions. The results turned out to be nearly identical for both approaches, so only the former analyses are reported here.

Figure 12.1 shows the mean reading times at each sentence position for object and subject relative clauses that contained head nouns. We focus first on just these two conditions because one important goal was to determine whether it is subject or object relative clauses that are more difficult to process in Mandarin. Figure 12.1 clearly shows that subject relatives were read more slowly than object relatives at almost every word position. This difference was reliable at the relative clause head noun (“official”: ( $F_1(1, 47) = 11.2, p < 0.01$ ;  $F_2(1, 78) = 11.2, p < 0.01$ ). This word immediately follows DE, which is the first unambiguous cue that the sentence begins with a relative clause, so this is the first position at which a difference between subject and object relative clauses can be attributed specifically to relative clause processing. The next word, the main clause subject noun (“reporter”), was

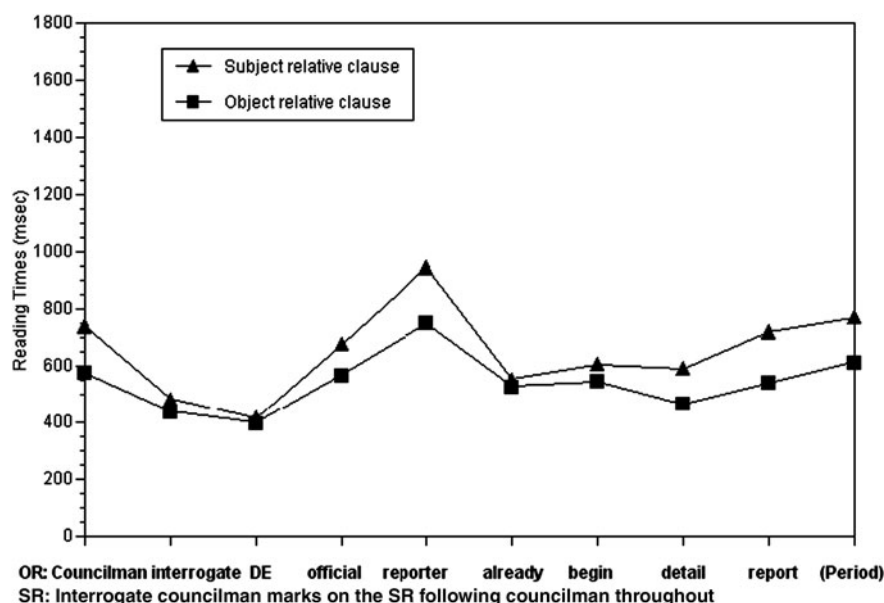


Fig. 12.1 Reading times for sentences with head noun present

also read more slowly in subject relative clauses ( $F_1(1,47) = 13.9$ ,  $p < 0.01$ ;  $F_2(1,78) = 16.8$ ,  $p < 0.01$ ). It is at this position that it first becomes apparent that the relative clause head noun is not also the main clause subject, since there is another noun to play that role, and therefore the sentence has some kind of topicalization, which probably explains why reading times at this word were the slowest in the sentence.

At the first two words in the sentence, it was not yet clear that there was a relative clause but these words were nonetheless read more slowly in subject relatives than in object relatives (word 1:  $F_1(1,47) = 14.0$ ,  $p < 0.05$ ,  $F_2(1,78) = 22.0$ ,  $p < 0.01$ ; word 2:  $F_1(1,47) = 14.6$ ,  $p < 0.05$ ,  $F_2(1,78) = 19.7$ ,  $p < 0.01$ ). This may have been in part because readers interpreted the sentence-initial verb in subject relatives as signaling the beginning of a subject relative but it could also have been more simply that it is less typical for a sentence to begin with a VN sequence than a NV sequence. Another likely factor is that there is more ambiguity about possible continuations following a VN sequence.

Subject relative sentences were read reliably more slowly than object relative sentences by both subjects and items at all of the rest of the words except for the word following the two-noun sequence (“already” in Fig. 12.1, which will be labeled “subject noun plus one” or “SN+1” here), which was reliable only by subjects. (DE:  $F_1(1,47) = 4.5$ ,  $p < 0.05$ ,  $F_2(1,78) = 4.8$ ,  $p < 0.05$ ; SN+1 (“already”):  $F_1(1,47) = 13.9$ ,  $p < 0.01$ ,  $F_2(1,78) = 1.1$ ,  $p < 0.05$ ; verb (“begin”):  $F_1(1,47) = 6.3$ ,  $p < 0.05$ ,  $F_2(1,78) = 3.0$ ,  $p < 0.01$ ; verb + 1 (“detail”):  $F_1(1,47) = 7.6$ ,  $p < 0.01$ ,  $F_2(1,49) = 5.6$ ,  $p < 0.05$ ; last word (“report”):

$F_1(1, 47) = 18.0, p < 0.05$ ;  $F_2(1, 78) = 16.2, p < 0.01$ ; sentence-final period:  $F_1(1, 47) = 4.6, p < 0.05$ ;  $F_2(1, 78) = 6.2, p < 0.05$ ). Thus, subject relative clauses were read more slowly than object relative clauses throughout the sentence, including at the first two words before it was clear there was a relative clause.

In the stimulus norming study, simple sentences in which the head nouns (e.g., “official”) played the subject role (see example 17 above) were rated as slightly more plausible than those in which the same head nouns played the object role (see example 18 above). Thus, it is unlikely that the subject relatives were read more slowly because readers found them generally less plausible.

Figure 12.2 shows the conditions with omitted head nouns superimposed on the head-present conditions that were shown alone in Fig. 12.1. The solid lines represent the conditions with head noun present and the dotted lines the conditions with head noun absent. Since the head noun was omitted in the conditions plotted with the dotted lines, there is a break in those lines in Fig. 12.2.

The sentence stimuli in the head-present and head-absent conditions were identical across the first three words and an omnibus ANOVA across all conditions at those positions showed no effects of head-presence (word 1:  $F_1(1, 47) = 2.7, p > 0.1$ ;  $F_2(1, 78) = 2.1, p > 0.1$ ; word 2:  $F_s < 1$ ; DE:  $F_s < 1$ ) and no interaction between relative clause type and head presence (words 1 and 2: all  $F_s < 1$ ; DE:  $F_1(1, 47) = 2.2, p > 0.1$ ;  $F_2(1, 78) = 3.3, p > 0.05$ ). Just as in the analysis described above that included only the head-present conditions, in the omnibus ANOVA subject relatives were read more slowly

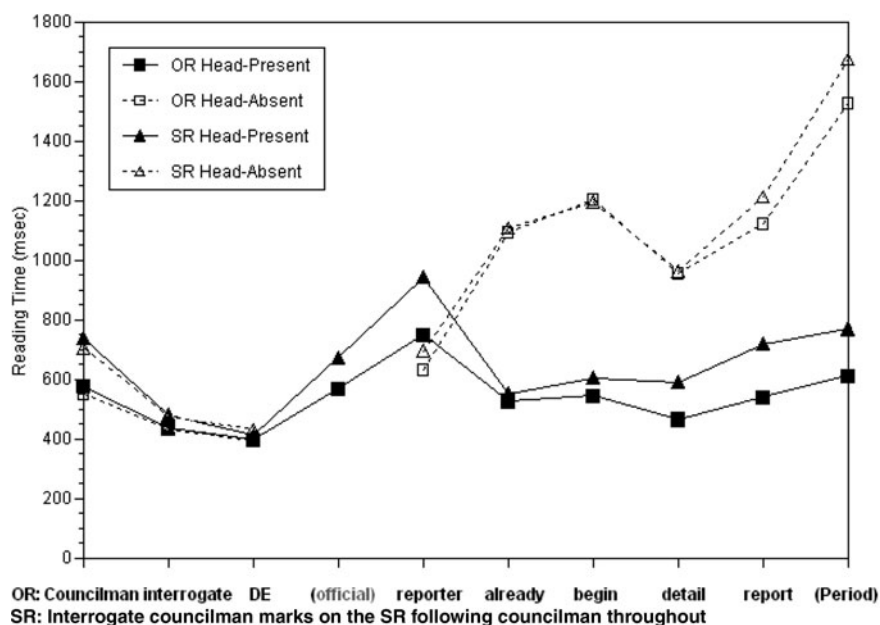


Fig. 12.2 Reading times for all sentence types in Experiment 1

overall than object relatives at all of the first three words (word 1:  $F_1(1, 47) = 22.3$ ,  $p < 0.01$ ;  $F_2(1, 78) = 50.8$ ,  $p > 0.01$ ; word 2:  $F_1(1, 47) = 31.7$ ,  $p < 0.01$ ;  $F_2(1, 78) = 37.7$ ,  $p < 0.01$ ; DE:  $F_1(1, 48) = 17.1$ ,  $p < 0.01$ ;  $F_2(1, 78) = 13.5$ ,  $p < 0.01$ ).

Sentences in the head-present and head-absent conditions first became different at the word following DE, which was the relative clause head noun in the head-present conditions (“official”) and the main clause subject noun in the head-absent conditions (“reporter”). A direct comparison of the results for these two different words will be postponed until after comparisons of the rest of the words that were identical across conditions. At the main clause subject noun (“reporter”), subject relatives continued to be read more slowly overall than object relatives ( $F_1(1, 47) = 14.1$ ,  $p < 0.01$ ;  $F_2(1, 78) = 17.1$ ,  $p < 0.01$ ). In the head-present conditions, this noun was the second in a two-noun sequence, while in the head-absent conditions it immediately followed DE rather than another noun, and this is reflected in the fact that this word was read more slowly overall in head-present sentences than in head-absent sentences ( $F_1(1, 47) = 11.8$ ,  $p < 0.01$ ;  $F_2(1, 78) = 44.4$ ,  $p < 0.01$ ). In addition, there was an interaction between head-presence and relative clause type at this word, such that differences between subject and object relatives were larger when the head was present than when it was absent ( $F_1(1, 47) = 6.6$ ,  $p < 0.05$ ;  $F_2(1, 78) = 5.2$ ,  $p < 0.05$ ).

Starting at the next word position and continuing throughout the rest of the sentence, differences between head-present and head-absent sentences reversed, with head-absent sentences read much more slowly than head-present sentences (SN+1 (“already”):  $F_1(1, 48) = 93.5$ ,  $p < 0.01$ ;  $F_2(1, 78) = 166.4$ ,  $p < 0.01$ ; verb (“begin”):  $F_1(1, 47) = 57.1$ ,  $p < 0.01$ ;  $F_2(1, 78) = 241.7$ ,  $p < 0.01$ ; verb+1 (“detail”):  $F_1(1, 47) = 86.8$ ,  $p < 0.01$ ;  $F_2(1, 49) = 116.3$ ,  $p < 0.01$ ; last word (“report”):  $F_1(1, 47) = 54.3$ ,  $p < 0.01$ ;  $F_2(1, 78) = 186.4$ ,  $p < 0.01$ ; sentence-final period:  $F_1(1, 47) = 75.6$ ,  $p < 0.01$ ;  $F_2(1, 78) = 245.9$ ,  $p < 0.01$ ). Across these same later word positions, differences between subject and object relatives disappeared at the word following the main clause subject noun in all conditions and then that overall difference re-emerged and became reliable again only at the last word ( $F_1(1, 47) = 17.4$ ,  $p < 0.01$ ;  $F_2(1, 78) = 10.7$ ,  $p < 0.01$ ) and the sentence-final period ( $F_1(1, 48) = 8.6$ ,  $p < 0.01$ ;  $F_2(1, 78) = 11.3$ ,  $p < 0.01$ ). (All Fs at both SN+1 and verb < 1; verb+1:  $F_1(1, 47) = 3.7$ ,  $p < 0.05$ ;  $F_2(1, 49) = 2.5$ ,  $p < 0.1$ ). Although it can be seen in Fig. 12.2 that the pattern of subject relatives being slower than object relatives re-emerged earlier in head-present conditions than in head-absent conditions, there were no interactions at any position after the main clause subject (all Fs < 2), except for the word after the verb in the subject analysis only (verb+1 (“detail”):  $F_1(1, 47) = 4.1$ ,  $p < 0.05$ ).

One additional analysis was conducted to directly compare the words immediately following DE, which were different words in the head-present and head-absent conditions, i.e., the relative head noun in the head-present conditions (“official”) but the main clause subject noun (“reporter”) in the head-absent conditions. We hypothesized that the main clause subject would initially be

mistaken as the relative clause head noun in the head-absent conditions and the reading times at that word were quite similar to those at the head noun in the head-present conditions (see Fig. 12.2). However, the main clause subject noun in the head-absent conditions was read more slowly overall than the relative clause head noun in the head-present condition ( $F_1(1,47) = 12.3$ ,  $p < 0.01$ ;  $F_2(1, 78) = 12.5$ ,  $p < 0.01$ ). Since different words are being compared, the overall reading time difference could be partly due to differences between the words, such as familiarity and/or the length and complexity of the characters. We do not have frequency of occurrence or familiarity information about the words and characters used in the stimuli but the number of strokes per word was counted as a measure of length and complexity. The relative clause head nouns had on average 18.5 strokes while the main clause subject nouns were slightly more complex with an average count of 20.6 strokes, which may at least partially explain why the latter were read more slowly. This word was also read more slowly overall in subject relatives than object relatives in the subject analysis ( $F_1(1, 47) = 5.5$ ,  $p < 0.05$ ) but that difference did not reach reliability in the item analysis ( $F_2(1, 79) = 3.5$ ,  $p = 0.06$ ). There was no interaction between head-presence and relative clause type in this comparison ( $F_s < 2$ ).

### 12.3 Discussion

The results for the head-present conditions replicated Hsiao and Gibson's original finding that subject relative clauses are harder to process than object relative clauses in Mandarin and do so for a different kind of sentence with the relative clauses modifying topicalized main clause objects. Furthermore, this difference was observed across most of the words in the sentence, in contrast with the more restricted differences found in most previous studies, probably because the topicalized structures were relatively difficult to process, thus amplifying differences, as Hsiao and Gibson's doubly embedded sentences did.

In the head-absent conditions, reading times slowed down dramatically starting at the word after the main clause subject noun ("already"). The word in this position was always an adverb or a quantifier or a verb such as "start" or "decide", which was followed later in the sentence by another verb, as in "decided to buy". Thus, the word in this position signaled that there would not be two sequential nouns but it did not unambiguously signal that there was no head noun for the relative clause, since the main clause subject noun could still be interpreted as both the relative head noun and the main clause subject. Reading times may have slowed down so much at this position because readers were considering both possible interpretations in parallel, i.e., that the one noun was both relative head noun and main clause subject, or that the relative was missing its head and the noun was only the main clause subject. For the latter possibility, it seems likely that the unusualness of both topicalization and an

omitted head noun in isolated sentences without any contextual support also contributed to the slow reading times starting at this position.

Of the various proposals to explain relative clause processing, the Word Order Frequency account, the Linear Distance account and Gibson's Dependency Locality Theory can all account for our results. The Accessibility Hierarchy, Perspective Shift and Structural Distance accounts all predict that object relatives should be harder in Mandarin and thus fail to account for our results. Because Dependency Locality Theory makes detailed predictions about the changing degree of difficulty at each word position in the sentences, it is tempting to derive similar predictions about word-by-word reading times. Such predictions do not fare very well, however. In particular, Dependency Locality Theory predicts higher processing cost at DE in subject relatives than in object relatives (see 15 above) but we found no reliable differences at this word. In addition, Dependency Locality Theory predicts the same processing costs for subject and object relatives across the main clause words but we found subject relatives to be harder than object relatives across those word positions. It is perhaps unfair to derive such predictions, however, since the relationship between processing cost and word-by-word reading times is likely to be complex, especially at high-frequency function words like DE, which tend to be read quickly.

An important property of the sentences used in Experiment 1 was that the main clause subject nouns were always animate and thus plausible potential head nouns for the relative clauses, so that when the relative head noun was missing it would be possible to mistake that noun as the head noun. That was changed in Experiment 2.

## 12.4 Experiment 2

In Experiment 1, we obtained evidence against the idea that object relative clauses are universally harder than subject relative clauses by showing that it is subject relatives that are harder to process in Mandarin sentences where the relative clauses modify topicalized main clause object nouns. The second experiment had two goals. The first was simply to replicate the finding in the first experiment that subject relatives are harder and the second was to investigate the role of a semantic cue, animacy, in resolving temporary ambiguity in Mandarin relative clauses.

In example (16b), repeated below in (19a), the animate main clause subject noun "reporter" immediately follows "DE" because the relative head noun has been dropped and it is plausible as a possible head noun for the relative clause, since reporters can both interrogate and be interrogated. The extreme difficulty that readers had in the head-absent conditions in Experiment 1 when it turned out that "reporter" was not the relative clause head suggests that it was initially misinterpreted as the head.

- (19) a. Mandarin object relative with head noun omitted and animate main clause subject  
 [議員 質詢 的 \_\_\_\_] 記者 已經 開始 詳細 報導。  
 [Councilman interrogate DE \_\_\_\_] reporter already begin detail report  
 (About [the person who the councilman interrogated], reporters have already begun to report in detail.)
- b. Mandarin object relative with head noun omitted and inanimate main clause subject  
 [議員 質詢 的 \_\_\_\_] 報紙 已經 開始 詳細 報導。  
 [Councilman interrogate DE \_\_\_\_] newspaper already begin detail report  
 (About [the person who the councilman interrogated], newspapers have already begun to report in detail.)

Compare (19a) to (19b), where the inanimate noun “newspaper” is not plausible as the relative clause head because an inanimate newspaper can neither interrogate nor be interrogated. In Experiment 2, we investigated whether making the main clause subject noun inanimate would prevent mistaking it as the relative clause head noun even though it immediately follows “DE” in the head-omitted conditions and thus alleviate the difficulty participants experienced in those conditions in Experiment 1.

In both English and Mandarin, word order is a strong cue about the sentential roles of noun phrases but English also has subject-verb number agreement cues that Mandarin does not. There is evidence that Mandarin speakers rely instead on the animacy of nouns to help determine their sentential roles. In off-line sentence interpretation studies testing the Competition Model developed by Bates and MacWhinney (1979) to explain cross-linguistic processing differences, Mandarin speakers have been found to treat animacy as equally important as word order, in contrast with English speakers, who tend not to rely on animacy even when word order is ambiguous and agreement cues are absent (Lin, 2005; Su, 2001). Thus, we might expect Mandarin speakers to make rapid use of the animacy of the main clause subject noun in our sentences to avoid interpreting it as the head noun when the head is omitted and so to have substantially less difficulty than in Experiment 1 with the head-absent conditions.

There has been considerable controversy about just how quickly semantic and pragmatic information come into play during sentence comprehension (e.g., Clifton et al., 2003; Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). Rather than reviewing all of the evidence in this area, we focus here on previous studies specifically investigating the impact of semantic and pragmatic factors on relative clause comprehension in different languages.

In both German and Dutch, the roles of nouns in sentences are indicated by case inflections in addition to word order and agreement. Case marking is sometimes ambiguous but word order and subject-verb agreement can often compensate. However, verbs are clause-final in relative clauses in both languages, so word order cues are disrupted and agreement cues become useful only at the verb at the end of the relative clause. Schriefers et al. (1995) took advantage of these properties to investigate the role of plausibility in relative clause comprehension in German. Across three studies, they found consistently



longer reading times on the disambiguating relative-clause-final auxiliary verb when it disambiguated toward an object relative, even when preceding pragmatic bias favored the object relative interpretation. The authors concluded that plausibility does not overrule a general preference for subject relatives in German. However, Mak, Vonk, and Schriefers (2002) argued that the absence of plausibility effects in Schriefers et al.'s studies was due to the fact that all of the relative clause head nouns were animate. In corpus studies of Dutch and German newspaper text, Mak et al. found object relatives to be common only when the head noun was inanimate. Animate nouns are more likely to play subject/agent roles and thus to be more felicitous in subject relatives, while inanimate nouns are more likely to play object/patient roles and thus be more felicitous in object relatives. In two reading time studies in Dutch, Mak et al. found object relatives to be as easy to understand as subject relatives when the object relatives had inanimate heads. In a similar series of studies, Traxler, Morris and Seely (2002) also found English object relatives to be as easy to read as subject relatives when their heads were inanimate. As in Schriefers et al.'s German studies, a plausibility manipulation in English did not eliminate the difficulty of object relatives when head nouns were animate.

Interestingly, Mandarin corpus studies conducted by Wu et al. (this volume) and Pu (2007) found similar effects of the animacy of the head noun, though they differed from each other in some of the details. In both studies, subject relatives were found to be more common when the head noun was animate and object relatives were more common when the head noun was inanimate, just as in Dutch (Mak et al., 2002). In addition, both studies found relative clauses modifying the matrix subject to be considerably more common than those modifying the matrix object and Wu et al. also found the preference for animate heads of subject relatives and for inanimate heads of object relatives to be especially strong when the relative modified the matrix subject. Thus, not surprisingly, it seems that the semantic and pragmatic factors that determine which kinds of relative clauses are likely to be used in Dutch also apply in Mandarin.

In the experimental studies of German, Dutch and English described above, the effects of animacy were observed at or after the end of the relative clause. Given that English relative clauses are head-initial and typically have a relative pronoun immediately following the head, the animacy of the head noun could start to influence expectations about the kind of relative clause to follow quite early. In an event-related brain potential (ERP) study of English, Weckerly and Kutas (1999) found effects of animacy beginning at the first noun, suggesting that good readers expected sentences to begin with animate nouns, but that when they began with inanimate nouns, object relative clauses were a better continuation than subject relatives.

In Experiment 1, because the relative clauses were constructed to require animate heads, animate main clause subject nouns were used so that it would be possible to mistake them for the relative clause head nouns when those were absent. One consequence of making both nouns animate is that it made them



similar to one another. The observation that similarity across the nouns in sentences with multiple embeddings can increase difficulty can be dated back to Miller and Chomsky's (1963) observations about multiply center-embedded relative clauses, illustrated in (20) below.

(20) The salmon that the man that the dog chased smoked fell.

Lewis and colleagues (1996; Lewis, Vasishth, & Van Dyke, 2006; Van Dyke & Lewis, 2003) promoted the notion of "similarity-based interference" to explain why sentences containing multiple words having similar properties can be more difficult to process than sentences whose words are less similar to one another. They argued that when multiple elements must be held in working memory during sentence processing in order to integrate them with later elements, the more similar those elements are, the more potentially confusable they are, making it more difficult to be sure to retrieve and integrate the right ones at the right times. Evidence supporting this general notion has been found in a number of recent studies (Fedorenko, Gibson, & Rohde, 2006; Gordon, Hendrick, & Johnson, 2001, 2004; Gordon, Hendrick, Johnson, & Lee, 2006; Gordon, Hendrick, & Levine, 2002; Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006; Warren & Gibson, 2002). For example, Gordon and colleagues (Gordon et al., 2001) used different noun phrase types, such as proper names and job descriptors (e.g., "Ethan" vs "the fireman"), to examine processing difficulty for English relative clauses. In addition to confirming that object relative clauses are the harder ones in English, they also found that reading times were slower when the two nouns in the sentence were of the same type. Warren and Gibson (2002) found that some doubly-embedded relative clauses only become acceptable when some of the nouns are pronouns and others full nouns, as illustrated in (21) below.

(21) The reporter who everyone that I met trusts said the president won't resign yet. (Bever, 1974)

Given the results of previous studies showing effects of animacy in Dutch and English relative clause processing (Mak et al., 2002; Traxler et al., 2002; Weckerly & Kutas, 1999), studies showing effects of animacy in other kinds of Mandarin sentences (Lin, 2005; Su, 2001), and studies showing similarity-based interference effects in English (Fedorenko et al., 2006; Gordon et al., 2001, 2002, 2004, 2006; Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006; Warren & Gibson, 2002), in Experiment 2 we used inanimate nouns as the main clause subject nouns in our sentences. For the sentences with head noun present, the goals were to determine whether making the two nouns less similar (i.e., animate relative clause head noun and inanimate main clause subject noun) would make the sentences easier to understand, as well as to replicate

the overall finding that subject relatives were more difficult in Experiment 1. For the sentences with head noun absent, the goal was to determine whether the implausibility of the inanimate main clause subject as the relative clause head noun would prevent people from pursuing that interpretation and thus make the sentences without head nouns easier than they were in Experiment 1.

## 12.5 Materials, Design and Procedure

The design and procedures for the second experiment were identical to the first. Forty participants from the same population of college students at National Taiwan Normal University as in Experiment 1 (approximate mean age 21) were paid a small sum for their participation. The only difference from Experiment 1 was that the main clause subject nouns were inanimate, as illustrated in (22) below. (This required a few other small changes to the main clause words in a few items to make the sentences completely felicitous.) In the stimulus norming study described above for Experiment 1, sentences like those in (22) below were included and they were rated as much less acceptable (1.65) than the versions with two animate nouns that were used in Experiment 1 (5.74 and 5.46). Thus the inanimate nouns used in Experiment 2 were indeed very poor potential relative clause heads in the head-absent conditions.

(22) The councilman interrogates the newspaper.

It is important to note that the sentences still contained two animate nouns in the relative clause itself, which is atypical for relative clauses, according to corpus studies (Mak et al., 2002; Pu, 2007; Wu et al., this volume) and which seems likely to make the sentences somewhat harder to understand. We will return to this point in the discussion.

There were again 80 sets of test sentences and 60 sets of fillers. Care was again taken to avoid possible compound interpretations of the two-noun sequence of the relative clause head noun followed by the main clause subject noun. The fillers were the same as in the first experiment. The paradigm was again self-paced, word-by-word reading.

- (23) a. Mandarin object relative clause modifying topicalized main clause object with head noun present  
       [議員        質詢        的    官員] 報紙        已經    開始    詳細    報導。  
       [Councilman interrogate DE official] newspaper already begin detail report  
       (About [the official who the councilman interrogated], newspapers have already begun to report in detail.)
- b. Mandarin object relative clause modifying topicalized main clause object with head noun omitted

[議員 質詢 的 \_\_\_\_] 報紙 已經 開始 詳細 報導。  
[Councilman interrogate DE \_\_\_\_] newspaper already begin detail report  
(About [the person who the councilman interrogated], newspapers have already begun to report in detail.)

c. Mandarin subject relative clause modifying topicalized main clause object with head noun present

[質詢 議員 的 官員] 報紙 已經 開始 詳細 報導。  
[Councilman interrogate DE official] newspaper already begin detail report  
(About [the official who interrogated the councilman], newspapers have already begun to report in detail.)

d. Mandarin subject relative clause modifying topicalized main clause object with head noun omitted

[質詢 議員 的 \_\_\_\_] 報紙 已經 開始 詳細 報導。  
[Interrogate councilman DE \_\_\_\_] newspaper already begin detail report  
(About [the person who interrogated the councilman], newspapers have already begun to report in detail.)

12.6 Results

The reading times in Experiment 2 are shown in Fig. 12.3 below, with solid lines representing conditions with head noun present and dashed lines representing conditions with head noun absent. A comparison of Fig. 12.3 with Fig. 12.2 reveals three important differences. First, it appears that subject relatives were

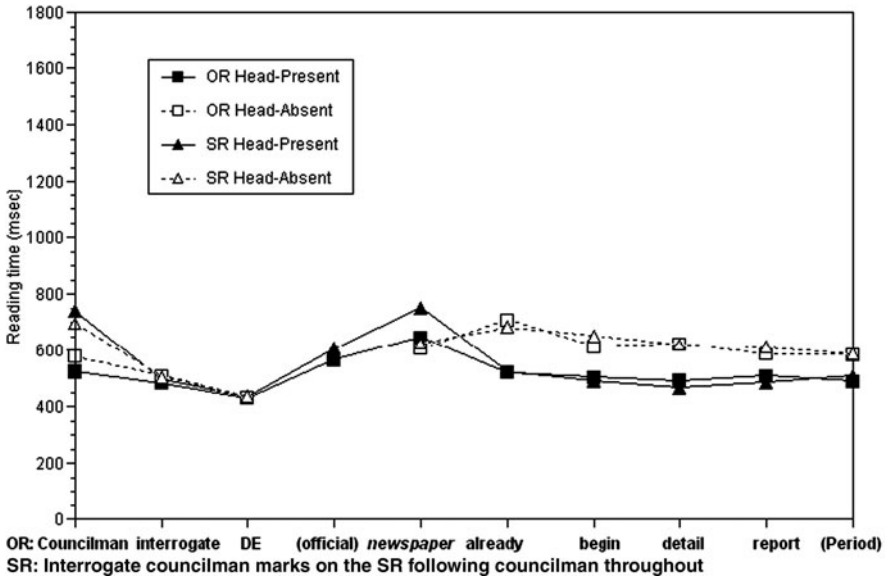


Fig. 12.3 Reading times for all sentence types in Experiment 2

again read more slowly than object relatives but at fewer word positions. Second, readers appeared to have less difficulty in the head-absent conditions in Experiment 2 than they did in Experiment 1. And third, there were no differences between subject and object relatives at the end of the sentence in Experiment 2, while there were in Experiment 1. Before further comparing the results across the two studies, however, we first present the analyses for Experiment 2 alone.

An omnibus ANOVA revealed that subject relative clauses were reliably read more slowly overall than object relative clauses at just the first word ( $F_1(1, 39) = 16.6, p < 0.01$ ;  $F_2(1, 79) = 89.7, p < 0.01$ ) and the main clause subject noun ("newspaper":  $F_1(1, 39) = 8.9, p < 0.01$ ;  $F_2(1, 79) = 12.8, p < 0.01$ ; all  $F_s < 2$  at other word positions). Since it was not yet clear at the first word that there was a relative clause, it is only the results at the main clause subject noun that unambiguously show subject relatives to be harder than object relatives. As in Experiment 1, the difference at the first word could be due to an expectation that the sentence will continue with a subject relative but could also reflect the fact that it is somewhat atypical for Mandarin sentences to begin with a verb and/or the fact that there is more ambiguity about possible continuations for a sentence that begins with a verb.

There were no main effects of head noun presence until the main clause subject noun, which was where the sentences in the head-present and head-absent conditions first became different (all  $F_s < 2$  for words preceding the main clause subject), except for a difference at the second word that was reliable by subjects and marginal by items ( $F_1(1, 39) = 4.5, p < 0.05$ ;  $F_2(1, 79) = 2.5, p < 0.1$ ). Since the head-present and head-absent sentences were still identical at the second word, this effect is inexplicable. The main clause subject noun itself was read more slowly in the head-present than the head-absent conditions, reliably by items and marginally by subjects ( $F_1(1, 39) = 3.8, p < 0.1$ ;  $F_2(1, 79) = 13.1, p < 0.01$ ). As in Experiment 1, the difference between head-present and head-absent conditions reversed at the word following the main clause subject noun, with the head-absent conditions read more slowly throughout the rest of the sentence (all  $F_s > 10$ , all  $p < 0.01$ ).

As in Experiment 1, there was an interaction between relative clause type and head noun presence such that the difference between subject and object relatives was larger in the head-present conditions than the head-absent conditions at the main clause subject noun, reliable by items and marginal by subjects ( $F_1(1, 39) = 2.7, p < 0.1$ ;  $F_2(1, 79) = 4.8, p < 0.05$ ). Unlike Experiment 1, there was a similar interaction at the first word in the sentence ( $F_1(1, 39) = 11.2, p < 0.01$ ;  $F_2(1, 79) = 8.6, p < 0.01$ ), which is inexplicable, since the head-present and head-absent conditions were identical at that point.

The reading times at the words immediately following DE, which differed in head-present and head-absent sentences, were directly compared and unlike Experiment 1, there were no reliable differences in this comparison (all  $F_s < 2.5$ , all  $p > 0.1$ ), even though the main clause subject noun

(“newspaper”) was again a bit more complex (22.8 strokes on average) than the relative clause head noun (“official”: 18.5 strokes on average).

## 12.7 Discussion

The second study confirmed the finding in Experiment 1 that subject relative clauses were more difficult overall than object relative clauses in Mandarin but the differences were more restricted, presumably because the sentences were easier because they contained inanimate main clause subject nouns that 1) could not be mistaken for the head nouns when those were missing and 2) were less confusable with the relative clause head nouns when those were present. Before further discussion of the results, an analysis combining the two studies will be reported.

## 12.8 Results Across Both Studies

To directly evaluate the effect of the animacy of the main clause subject noun, an analysis was conducted on the combined results of the two studies, starting from the relative clause head noun.<sup>3</sup> Since the sentences did not yet differ across studies at the relative clause head noun itself, the only effect was that head nouns were read more slowly overall in subject relatives than in object relatives (640 vs 566 msec;  $F_1(1, 86) = 11.3$ ,  $p < 0.01$ ;  $F_2(1, 157) = 10.3$ ,  $P < 0.01$ ), as was found in each study separately. This effect of relative clause type continued at the main clause subject noun itself, which was read more slowly following subject relatives than following object relatives (755 vs 658 ms;  $F_1(1, 86) = 20.8$ ,  $p < 0.01$ ;  $F_2(1, 157) = 24.3$ ,  $p < 0.01$ ). The overall difference between subject and object relatives then disappeared at the next two word positions but re-emerged on the last word of the sentence (757 vs 689 ms;  $F_1(1, 86) = 12.7$ ,  $p < 0.01$ ;  $F_2(1, 157) = 9.3$ ,  $p < 0.01$ ) and the sentence-final period (885 vs 803 ms;  $F_1(1, 86) = 7.8$ ,  $p < 0.01$ ;  $F_2(1, 157) = 11.0$ ,  $p < 0.01$ ). In addition, the main effect of head presence that was observed at the main clause subject noun in each study separately also carried over into the analysis combining studies. This word was read more slowly when it was the second noun in a two-noun sequence (because it immediately followed the head noun in the head-present conditions) than when it immediately followed DE

<sup>3</sup> Animacy was treated as a between-subjects factor and the item-based analysis across both studies was done in two different ways, with animacy treated as a between-items factor in one and as a within-items factor in the other. It was not obvious which was the more appropriate approach because the items were very similar but not identical across studies except for the animacy manipulation, because a few items had to be modified in other ways to remain felicitous in Experiment 2. The patterns of reliability were identical in both item-based analyses, so only the between-items version is reported here.

(because the head noun was absent) (773 vs 639 ms;  $F_1(1,86) = 14.3$ ;  $p < 0.01$ ;  $F_2(1,157) = 55.2$ ,  $p < 0.01$ ). At all subsequent positions, however, once it became clear that the main clause subject noun was not the relative clause head noun in the head-absent conditions, the direction of this effect reversed, with head-absent conditions read more slowly than head-present ones throughout the rest of the sentence (all  $F_s > 90$ , all  $p < 0.01$ ). Finally, the interaction between relative clause type and head presence that was observed at the main clause subject noun (and not at any subsequent positions) separately in each study also carried over into the combined analysis ( $F_1(1,86) = 8.7$ ,  $p < 0.01$ ;  $F_2(1,157) = 9.8$ ,  $p < 0.01$ ), reflecting the fact that the difference between subject and object relatives was larger when the head noun was present than when it was absent (129 ms difference vs 63 ms difference)

Most important in this analysis were a number of effects of animacy starting at the main clause subject noun, which was the noun whose animacy was manipulated. Animate main clause subject nouns themselves were read more slowly overall than inanimates (755 vs 657 ms), producing a reliable main effect of animacy in the item-based analysis only ( $F_1 < 2$ ;  $F_2(1,157) = 19.7$ ,  $p > 0.01$ ). There was also an interaction between animacy and head-noun-presence starting at the main clause subject noun and persisting throughout the rest of the sentence, which arose because the difficulty due to an absent relative clause head noun was substantially mitigated when the main clause subject noun was inanimate and thus could not be mistaken as the head. At the main clause subject noun itself, this effect was reliable only by items ( $F_1 < 2$ ;  $F_2(1,157) = 7.5$ ,  $p < 0.01$ ) but throughout the rest of the sentence it was reliable in both analyses (all  $F_s > 20$ , all  $p < 0.01$ ). Interactions between animacy and relative clause type emerged starting at the next-to-last word in the sentence, where they were marginal by both subjects and items ( $F_1(1,86) = 3.24$ ,  $p < 0.1$ ;  $F_2(1,99) = 3.0$ ,  $p < 0.1$ ) and then became reliable at the last word and the period (all  $F_s > 9$ , all  $p < 0.01$ , except for the subject-based analysis at the sentence-final period, where  $F_1(1,86) = 5.8$ ,  $p < 0.05$ ). Finally, the three-way interaction among animacy, relative clause type and head-presence did not reach reliability at any position, though it was marginal for the last three words in the sentence (all  $F_s > 2.5$ , all  $p < 0.1$ ), reflecting the fact that differences between subject and object relatives re-emerged at these positions but only when the main clause subject noun was animate and the head noun was present. Simple effects tests supported this interpretation of the marginal three-way interaction, since the two-way interaction of animacy and relative clause type was reliable at these three words only when the head noun was present (all  $F_s > 7$  and  $p < 0.01$  for the last two words, and  $F_1(1,86) = 5.0$ ,  $p < 0.05$ ;  $F_2(1,157) = 2.9$ ,  $p < 0.1$  for the third-to-last word). There were no similar two-way interactions between animacy and relative clause type at any of these word positions when the head noun was absent (all  $F_s < 2$ , all  $p > 0.1$ ).

## 12.9 General Discussion

In both experiments, object relatives were read more quickly than subject relatives at multiple word positions. This was especially true when the relative clause head noun was present but was also found to a lesser extent when the head noun was absent. The finding that object relatives were easier than subject relatives is consistent with the predictions of the Word Order Frequency, Linear Distance and Dependency Locality Theory accounts for asymmetry in relative clause processing difficulty and inconsistent with the predictions of the Accessibility Hierarchy, Perspective Shift and Structural Distance accounts. It appears that Mandarin object relative clauses are easier to process than subject relatives, probably because their canonical SVO word order 1) is more frequent, 2) makes the linear distance between filler and gap shorter and 3) thereby decreases the storage and integration costs incurred during processing. Differences in our studies were more robust than in previous studies of Mandarin relative clauses, except for Wu and Gibson's (2008) study, which also found large differences. We believe the size of the effects in our studies was probably due to using relatively difficult sentences with relative clauses modifying topicalized main clause objects, while Wu and Gibson (2008) argued that their differences were large because all temporary ambiguity was removed by using contexts that made relative clauses virtually certain.

In addition to contributing to the growing body of evidence about relative clause processing in different languages, our studies also examined the role of animacy in disambiguating sentences whose relative clause heads were omitted, as is allowed in Mandarin. Using relative clauses that modified topicalized main clause objects and including conditions where the relative clause head nouns were omitted allowed us to create temporary ambiguity about whether or not the noun immediately following DE was the head noun of the relative clause. Topicalized main clause objects were used so that when the relative clause head noun was omitted, the main clause subject noun was the word immediately following DE and thus could be mistaken as the relative head noun. The relative clauses were constructed to require animate head nouns, so that when the noun immediately following DE in the head-absent conditions was inanimate (as in Experiment 2), readers might be able to use that cue to avoid being garden-pathed into thinking that the main clause subject noun was the relative head noun. Readers had much less difficulty in the head-absent conditions in Experiment 2 than in Experiment 1, showing that they were indeed able to make rapid use of the animacy cue to rule out the possibility that the main clause subject noun was the relative head noun in the head-absent conditions.

Although using topicalized relative clauses and omitting their heads allowed us to investigate the usefulness of animacy cues in Mandarin sentence comprehension, using such sentences without any discourse context naturally raises concerns about the generalizability of the results to relative clause processing in



other more typical kinds of sentences. Topicalization and head-dropping are probably felicitous only in discourse contexts that promote them. However, in a series of more recent studies using non-topicalized sentences containing relative clauses whose heads were always present, we have consistently found subject relatives to be read more slowly than object relatives (Lin & Garnsey, 2009). Thus, we do not believe that the general pattern of results reported here is limited to the particular kinds of sentences we used. However, in both the studies reported here and in our more recent studies, the two nouns in the relative clause were usually both animate, which is atypical for relative clauses according to corpus studies (Mak et al., 2002; Pu, 2007; Wu et al., this volume), so it remains to be seen whether our results will generalize to sentences with relative clauses involving at least one inanimate noun.

A puzzle remains about how to resolve the apparent discrepancy between results like ours showing that Mandarin subject relatives are harder to understand with the higher frequency of occurrence of subject relatives observed in analyses of Mandarin corpora (Wu et al., this volume; Pu, 2007). Given that communication goals and most components of the language production process should be highly similar across languages, it is not surprising that similar frequencies of occurrence for subject and object relatives are observed across languages. However, it is rather surprising that Mandarin comprehenders apparently end up having to deal more often with a structure that is harder for them to understand. As described earlier in our introduction, in the case of Mandarin the several factors that have been invoked to explain differences in the processing difficulty of subject and object relative clauses make different predictions. Perhaps the relative weights of these various factors differ for production and comprehension, leading to the discrepancy. Additional evidence that there are conflicting pressures in Mandarin comes from the relatively small effect sizes and mixed pattern of results across studies using Mandarin sentences that are not made more complex by double embeddings or topicalization. Perhaps which kind of relative clause is more difficult to understand is simply not as consistent in Mandarin as it is in English, where the various relevant factors all point in the same direction. Thus, there may be more room in Mandarin for various other factors to influence relative clause processing, resulting in a mixed pattern of results across studies.

Finally, our results provide new evidence supporting the role of similarity-based interference during sentence processing. In Experiment 1, where the relative clause head noun and the main clause subject noun were similar because both were animate, the difficulty of subject relatives persisted throughout the sentence but in Experiment 2 where the nouns were less similar because one was animate and the other inanimate, the difficulty of subject relatives did not persist. Because the sentences were not fully disambiguated until an obligatorily transitive verb appeared at the end of the sentence, readers could not fully integrate earlier elements of the sentence until then and thus suffered additional processing cost when the elements they were forced to continue holding onto were more similar. This is the first instance we know of where a semantic feature



such as animacy, rather than the pronoun/noun/name status of nouns or syntactic functions of nouns, has been observed to contribute to similarity-based interference.

## References

- Altmann, G., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition*, 38, 419–439.
- Bates, E., & MacWhinney, B. (1979). A functionalist approach to the acquisition of grammar. In E. Ochs & B. Schieffelin (Eds.), *Developmental pragmatics* (pp. 167–209). New York: Academic Press.
- Bever, T. G. (1970). Cognitive basis for linguistic structures. In J. R. Hayes (Ed.), *Cognition and the development of language* (pp. 279–362). New York: Wiley.
- Bever, T. G. (1974). The ascent of the specious, or there's a lot we don't know about mirrors. In D. Cohen (Ed.), *Explaining linguistic phenomena* (pp. 173–200). Washington, D.C.: Hemisphere.
- Carreiras, M., Duñabeitia, J. A., Vergara, M., Zieza, I., & Laka, I. (2007). *Object relative clause preference in Basque: Subject relative clauses are not universally easier to process*. Presented at the Architectures and Mechanisms of Language Conference, Turku, Finland.
- Chen, B., Ning, A., Bi, H., & Dunlap, S. (2008). Chinese subject-relative clauses are more difficult to process than the object-relative clauses. *Acta Psychologica*, 129, 61–65.
- Christianson, K., Hollingworth, A., Halliwell, J. F., & Ferreira, F. (2001). Thematic roles assigned along the garden path linger. *Cognitive Psychology*, 42, 368–407.
- Chu, C., & Chi, T. J. (1999). *A cognitive-functional grammar of Mandarin Chinese*. Taipei: The Crane Publishing Co.
- Clifton, C., Traxler, M. J., Mohamed, M. T., Williams, R. S., Morris, R. K., & Rayner, K. (2003). The use of thematic role information in parsing: Syntactic processing autonomy revisited. *Journal of Memory & Language*, 49, 317–334.
- Cohen, L., & Mehler, J. (1996) Click monitoring revisited: An on-line study of sentence comprehension. *Memory & Cognition*, 24, 94–102.
- Fedorenko, E., Gibson, E., & Rohde, D. (2006). The nature of working memory capacity in sentence comprehension: Evidence against domain-specific working memory resources. *Journal of Memory & Language*, 54, 541–553.
- Ferreira, F., & Clifton, C. Jr. (1986). The independence of syntactic processing. *Journal of Memory & Language*, 25, 348–368.
- Fox, B. (1987). The noun phrase accessibility hierarchy reinterpreted: Subject primacy or the absolutive hypothesis. *Language*, 63, 856–870.
- Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition*, 68, 1–76.
- Gibson, E. (2000). The dependency locality theory: a distance-based theory of linguistic complexity. In Y. Miyashita, A. Marantz & W. O'Neil (Eds.), *Image, language, brain* (pp. 95–126). Cambridge, MA: MIT Press.
- Gibson, E., & Pearlmutter, N. (1998). Constraints in sentence comprehension. *Trends in Cognitive Science*, 2, 262–268.
- Gordon, P. C., Hendrick, R., & Johnson, M. (2001). Memory interference during sentence comprehension. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 27, 1411–1423.
- Gordon, P. C., Hendrick, R., & Johnson, M. (2004). Effects of noun phrase type on sentence complexity. *Language & Cognitive Processes*, 51, 97–114.
- Gordon, P. C., Hendrick, R., Johnson, M., & Lee, Y. (2006). Similarity-based interference during language comprehension: Evidence from eye tracking during reading. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 32, 1304–1321.

- Gordon, P. C., Hendrick, R., & Levine, W. H. (2002). Memory-load interference in syntactic processing. *Psychological Science*, 13, 425–430.
- Grodner, D., Gibson, E., & Tunstall, R. (2002). Syntactic complexity in ambiguity resolution. *Journal of Memory and Language*, 46, 267–295.
- Hawkins, J. (2004). *Efficiency and complexity in grammar*. Oxford: Oxford University Press.
- Hsiao, F., & Gibson, E. (2003). Processing relative clauses in Chinese. *Cognition*, 90, 3–27.
- Hsu, C.-C. N., & Chen, J.-Y. (2007). *A new look at the subject-object asymmetry: The effects of linear distance and structural distance on the processing of head-final relative clauses in Chinese*. Presented at the Conference on Interdisciplinary Approaches to Relative Clauses, Cambridge.
- Hsu, C.-C. N., Hurewitz, F., & Phillips, C. (2006). *Contextual and syntactic cues for processing head-final relative clauses in Chinese*. Presented at the 19th Annual CUNY Conference on Human Sentence Processing, New York, NY.
- Hsu, C.-C. N., Phillips, C., & Yoshida, M. (2005). *Cues for head-final relative clauses in Chinese*. Presented at the 18th Annual CUNY Conference on Human Sentence Processing, Tucson, AZ.
- Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, 98, 122–149.
- Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language & Cognitive Processes*, 15, 159–201.
- Keenan, E. L. & Comrie, B. (1997). Noun phrase accessibility and universal grammar. *Linguistic Inquiry*, 8, 63–99.
- King, J., & Just, M. A. (1991). Individual differences in syntactic processing: The role of working memory. *Journal of Memory & Language*, 30, 580–602.
- Kuo, K., & Vasishth, S. (2007). Processing Chinese relative clauses: Evidence for the universal subject preference. Unpublished manuscript.
- Kwon, N., Polinsky, M., & Kluender, R. (2006). Subject preference in Korean. In D. Baumer, D. Montero & M. Scanlon (Eds.), *Proceedings of the 25th West Coast Conference on Formal Linguistics* (pp. 1–14). Somerville, MA: Cascadilla Proceedings Project.
- Lewis, R. L. (1996). Interference in short-term memory: The magical number two (or three) in sentence processing. *The Journal of Psycholinguistic Research*, 25, 93–115.
- Lewis, R. L., Vasishth, S., & Van Dyke, J. A. (2006). Computational principles of working memory in sentence comprehension. *Trends in Cognitive Sciences*, 10, 447–454.
- Lin, Y. (2005). *Word order, animacy, and agreement cues in sentence processing by L1 Mandarin EFL learners*. Presented at the Midwestern Conference on Culture, Language, and Cognition, Northwestern University, IL.
- Lin, C.-J. (2006). *Grammar and parsing: A typological investigation of relative clause processing*. Ph.D dissertation, University of Arizona.
- Lin, C.-J., & Bever, T. G. (this volume). Garden path and the comprehension of head-final relative clauses. In H. Yamashita, Y. Hirose & J. Packard (Eds.), *Processing and producing head-final structures*. Dordrecht: Springer.
- Lin, Y., & Garnsey, S. M. (2009). The contributions of classifiers and pronouns to Mandarin relative clause comprehension. Presented at the 22nd Annual CUNY Conference on Human Sentence Processing, Davis, CA.
- Liu, A. K.-L. (2005). The structure of relative clauses in Jianshi Squliq Atayal. *Concentric: Studies in Linguistics*, 31, 89–110.
- MacDonald, M. C., & Christiansen, M. H. (2002). Reassessing working memory: A comment on Just & Carpenter (1992) and Waters & Caplan (1996). *Psychological Review*, 109, 35–54.
- MacWhinney, B., & Pleh, C. (1988). The processing of restrictive relative clauses in Hungarian. *Cognition*, 29, 95–141.
- Mak, W., Vonk, W., & Schriefers, H. (2002). The influence of animacy on relative clause processing. *Journal of Memory & Language*, 47, 50–68.

- Miller, G. A., & Chomsky, N. (1963). Finitary models of language users. In R. D. Luce, R. R. Bush & E. Galanter (Eds.), *Handbook of mathematical psychology* (Vol. II, pp. 419–491). New York: Wiley.
- Miyamoto, E., & Nakamura, M. (2003). *Subject/object asymmetries in the processing of relative clauses in Japanese*. Presented at the 22nd West Coast Conference on Formal Linguistics. Somerville, MA: Cascadilla Press.
- O'Grady, W. (1997). *Syntactic development: The acquisition of English*. Chicago, IL: University of Chicago Press.
- Packard, J., Ye, Z., & Zhou, X. (this volume). Filler-gap processing in Mandarin relative clauses: Evidence from Event-related potentials. In H. Yamashita, Y. Hirose, & J. Packard (Eds.), *Processing and producing head-final structures*. Dordrecht: Springer.
- Pu, M. M. (2007). The distribution of relative clauses in Chinese discourse. *Discourse Processes*, 43, 25–53.
- Real, F., & Christiansen, M. H. (2007). Processing of relative clauses is made easier by frequency of occurrence. *Journal of Memory & Language*, 53, 1–23.
- Schriefers, H., Friederici, A. D., & Kuhn, K. (1995). The processing of locally ambiguous relative clauses in German. *Journal of Memory & Language*, 34, 499–520.
- Su, I. R. (2001). Context effects on sentence processing: A study based on the competition model. *Applied Psycholinguistics*, 22, 167–189.
- Tabor, W., Juliano, C., & Tanenhaus, M. K. (1997). Parsing in a dynamical system: an attractor-based account of the interaction of lexical and structural constraints in sentence processing. *Language & Cognitive Processes*, 12, 211–272.
- Traxler, M. J., Morris, R. K., & Seely, R. E. (2002). Processing subject and object relative clauses: evidence from eye movements. *Journal of Memory & Language*, 47, 69–90.
- Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language*, 33, 285–318.
- Ueno, M., & Garnsey, S. (2008). An ERP study of the processing of subject and object relative clauses in Japanese. *Language & Cognitive Processes*, 23, 646–688.
- Van Dyke, J. A., & Lewis, R. (2003). Distinguishing effects of structure and decay on attachment and repair: A cue-based parsing account of recovery from misanalyzed ambiguities. *Journal of Memory & Language*, 49, 285–316.
- Van Dyke, J. A., & McElree, B. (2006). Retrieval interference in sentence comprehension. *Journal of Memory & Language*, 55, 157–166.
- Warren, T., & Gibson, E. (2002). The influence of referential processing on sentence complexity. *Cognition*, 85, 79–112.
- Weckerly, J., & Kutas, M. (1999). An electrophysiological analysis of animacy effects in the processing of object relative sentences. *Psychophysiology*, 36, 559–570.
- Wu, F.-Y., Haskell, T., & Andersen, E. (2006). *The interaction of lexical, syntactic, and discourse factors in on-line Chinese parsing: Evidence from eye-tracking*. Presented at the 19th Annual CUNY Conference on Human Sentence Processing, New York, NY.
- Wu, F., Kaiser, E., & Andersen, E. (this volume). Subject preference, head animacy, and lexical cues: A corpus study of relative clauses in Chinese. In H. Yamashita, Y. Hirose & J. Packard (Eds.), *Processing and producing head-final structures*. Dordrecht: Springer.
- Wu, H.-H. I., & Gibson, E. (2008). *Processing Chinese relative clauses in context*. Poster presented at the 21st annual CUNY Conference on Human Sentence Processing, Chapel Hill, NC.
- Yang, C.-L., Johnson, M., & Gordon, P. C. (2008). *The effect of contrasting linear ordering of filler-gap dependency in the processing of sentence integration: Evidence from the processing of relative clauses in Chinese*. Presented at the CUNY Conference on Human Sentence Processing, Chapel Hill, NC.
- Yoshida, M., Aoshima, S., & Phillips, C. (2004). *Relative clause prediction in Japanese*. Presented at the 17th Annual CUNY Conference on Human Sentence Processing, College Park, MD.