



# Syntactic representation of missing-verb anomalous utterances in Mandarin: Evidence from structural priming

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Accepted: 20 February 2023 / Published online: 7 March 2023  
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## Abstract

Theories of how people interpret utterances with verb-related anomalies are chiefly based on English, but relatively little is known about the syntactic representation of missing-verb anomalous utterances in Mandarin, which has strikingly different typological features. In the current study, two experiments in structural priming paradigm were carried out to investigate whether native Mandarin speakers reconstructed a full syntactic form of missing-verb anomalous utterances. Our study shows that the magnitude of priming following a missing-verb anomalous sentence is equivalent to that following an error-free sentence, indicating that native Mandarin speakers reconstruct a full syntactic representation of missing-verb anomalous utterances. The results thus provide robust evidence for the syntactic reconstruction account.

**Keywords** Missing-verb anomalous utterances · Syntactic reconstruction account · Mandarin · Structural priming

## Introduction

In daily communication, it is common that people encounter anomalous utterances in some conditions, such as in a noisy environment. For example, in Mandarin people might hear some missing-verb anomalous utterances such as *Zhangfu qizi yitiao qunzi* (*The husband the wife a skirt*) in which a verb is missing between *zhangfu* (*the husband*) and *qizi* (*the wife*), with the possible meaning that the husband gave the wife a skirt. Despite the incompleteness and ungrammaticality, people are more likely to interpret such missing-verb anomalous utterances smoothly. Some questions merit consideration. Do native Mandarin speakers reconstruct a full syntactic representation of missing-verb anomalous utterances? Do people from different linguistic backgrounds process missing-verb anomalous utterances in the same manner?

Two accounts (i.e., the syntactic non-reconstruction account and the syntactic reconstruction account) hold different views on the comprehension of missing-verb

anomalous utterances (see Ivanova et al., 2017, for a discussion). According to the syntactic non-reconstruction account, people may utilize some cues such as world knowledge or animacy instead of reconstructing the complete structure to understand the missing-verb anomalous sentences. In contrast, the syntactic reconstruction account assumes that comprehenders are more likely to process an anomalous sentence without a verb in the same manner as they arrive at an interpretation of an error-free sentence by reconstructing the full structure.

## Using structural priming to discriminate between the syntactic non-reconstruction account and the syntactic reconstruction account

One powerful tool that can be used to discriminate between the syntactic non-reconstruction account and the syntactic reconstruction account is structural priming. It refers to a linguistic phenomenon where speakers are prone to reuse the same syntactic forms they have recently used or heard in previous circumstances (Bock, 1986; Ferreira & Bock, 2006). For example, speakers are more likely to produce a Double Object dative (e.g., *The manager lent the employee a desk*) to describe a dative event after exposure to a Double Object (DO) sentence (e.g., *The King gave the queen a diamond ring*) than after a Prepositional Object (PO) sentence (e.g., *The King gave a diamond ring to the queen*).

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Despite the occurrence of the lexical boost effect when the repetition of the verb has a facilitation effect on a stronger priming, priming is not dependent upon the repetition of content words (Pickering & Branigan, 1998), closed-class lexical items (Bock, 1989), metric structure, and semantic information (Bock & Loebell, 1990).

Structural priming has been used to study language comprehension (e.g., Arai et al., 2007). Additionally, priming occurs in a bidirectional way between comprehension and production, with structural priming from comprehension to production (e.g., Bock et al., 2007) and facilitating effects of production on comprehension (e.g., Branigan et al., 2005). Such cross-modality priming lends considerable support to the previous comprehension-to-production structural priming studies (e.g. Cai et al., 2013, 2015; Ivanova et al., 2017) and the current study.

The structural priming paradigm has also proven to be an effective way to investigate the syntactic representation of missing-verb anomalous utterances since it is sensitive to the impact of verbs on the priming effects (Bernolet & Hartsuiker, 2010; Chang et al., 2015; Melinger & Dobel, 2005; Pickering & Branigan, 1998; Salamoura & Williams, 2006). More importantly for our research, structural priming was also employed to study how people comprehended elliptical expressions (Cai et al., 2013, 2015) and anomalous utterances (e.g., Ivanova et al., 2012, 2017). Taken together, the structural priming paradigm is a reasonable choice for this research.

### The representation of missing-verb anomalous utterances during processing

For the processing of missing-verb anomalous utterances, the syntactic non-reconstruction account assumes that comprehenders may adopt a good-enough comprehension strategy (see Goldberg & Ferreira, 2022, for a review; Ferreira et al., 2002; Sanford & Sturt, 2002) by constructing an imperfect syntactic representation (Christianson et al., 2001; Ferreira, 2003; Gibson & Thomas, 1999) under some difficult processing circumstances. Gibson and Thomas (1999) found that people tended to give up constructing a full syntactic structure because of the overloaded working memory caused by the high complexity of syntactic structure since they accepted missing verb-phrase ungrammatical sentences such as “The ancient manuscript that the graduate student who the new card catalog had confused a great deal was missing a page.” In addition, some previous studies (e.g., Ferreira, 2003; Kim & Osterhout, 2005; Kolk et al., 2003; Kuperberg et al., 2003; van Herten et al., 2005) show that comprehenders rely on plausibility or heuristics instead of the syntactic structure for an interpretation. For example, Kim and Osterhout (2005) found that comprehenders preferred to regard the hearty meal as the theme in the

implausible sentence “*The hearty meal was devouring the kids*” without regard to the syntactic analysis.

These studies appear to support the conjecture that the processing difficulty in accessing the verb may lead comprehenders to neglect the missing structural component for a good-enough analysis by combining the meaning of each word and other non-syntactic information such as plausibility (e.g., Ferreira, 2003; Kim & Osterhout, 2005) to derive an interpretation. There is a plausible explanation of this conjecture. To be specific, the recovery of verb position still fails to obtain some important verb information such as the spelling and meaning. With the limited verb information, the laborious reconstruction of a full-form structure is less likely to make more contributions to an optimal interpretation, which might not make any difference to the adoption of a good-enough comprehension strategy. It therefore seems plausible that people are expected to process missing-verb anomalous utterances in a more economical manner instead of constructing a complete syntactic representation.

In contrast, the alternative view is that a full syntactic representation carries great weight in the comprehension of missing-verb anomalous utterances since comprehenders endeavor to compute an enriched interpretation (Traxler et al., 2002). According to the noisy-channel account (Gibson et al., 2013), comprehenders are inclined to attribute the implausibility of an utterance (e.g., “*The mother gave the candle the daughter*”) to the noise they perceive instead of gleaning the literal meaning. By means of string edits (insertions and deletions), a semantically plausible sentence is reconstructed for a more likely interpretation. In a latest English structural priming study, Cai et al. (2022) found that native English speakers reconstructed the syntactic structure of implausible sentences such as “*The mother gave the candle the daughter*” by adding a preposition to ahead of *the daughter* for a nonliteral but plausible interpretation. Another structural priming study (Cai et al., 2015) on plausible sentences shows that native Mandarin speakers constructed a full syntactic representation when they were confronted with a dative sentence involving a missing direct-object argument. These studies provide a more likely possibility that special emphasis is given to the missing verb for an intact interpretation, which provides an important impetus for the reconstruction of missing-verb anomalous utterances.

Among all the prior literature, only Ivanova et al. (2017) provided compelling evidence of processing missing-verb anomalous utterances to distinguish these two accounts. Aiming to investigate how native English speakers processed the missing-verb anomalous utterances such as “*The waitress the book to the monk*,” Ivanova et al. conducted two structural priming experiments by manipulating the prime verb type and the prime construction of the experimental primes. Their results showed that the anomalous prime

sentences containing a missing verb had the same priming effects as the well-formed prime sentences, which provided robust evidence for the syntactic reconstruction account. But a question raised is whether the findings of Ivanova et al. (2017) are applicable to other languages with strikingly different typological features such as Mandarin.

### The potential influence of typological differences on the processing of missing-verb anomalous utterances

The typological parameters of English and Mandarin lead to discrepancies in sentence processing, which provides a possibility that native Mandarin speakers are more likely to use semantic information to interpret the missing-verb anomalous utterances without relying on a full syntactic representation. As a word-order dominant language, English places more weight on syntactic information such as word order in sentence interpretation (Bates et al., 1982; Cai & Dong, 2007; Liu et al., 1992; MacWhinney et al., 1984; McDonald, 1987). Conversely, Mandarin presents a different picture. Termed an *isolating language*, Mandarin has an impoverished morphosyntactic system that lacks morphological markers for case, number, person, or tense (Huang et al., 2016; Li & Thompson, 1989). Furthermore, in Mandarin the word order has a higher level of flexibility, which is mainly due to the fact that “the order in which basic words and phrases occur is governed to a large extent by considerations of meaning rather than of grammatical functions” (Li & Thompson, 1989, p. 19). The word orders such as SVO (subject, verb, object), OSV, SOV, VOS are allowable in Mandarin and the subject can be omitted (VO) in a clear context, which shows that the word order is not a reliable cue for the identification of the subject or object role (Li et al., 1993). Thus, native Mandarin comprehenders tend to utilize some pragmatic or semantic cues such as animacy instead of relying more on some syntactic cues such as word order and case markers (Cai & Dong, 2007; Li et al., 1992, 1993; Liu et al., 1992). For example, Cai and Dong (2007) found that word order cue played the most important role for native English speakers, whereas for native Mandarin speakers animacy took a leading role in the comprehension of the English and Mandarin sentences involving non-word verbs (e.g., *pesit* or *hocate*). In addition, Cai et al. (2013) conducted a structural priming study to investigate how native Mandarin speakers process verb-phrase ellipsis. They found that the magnitude of priming following an elliptical expression in Mandarin was less than that following a full-form prime, but was roughly equivalent to that following a baseline prime, suggesting that native Mandarin speakers interpreted utterances via a semantic representation instead of reconstructing the syntactic structure when processing verb-phrase ellipsis.

For Mandarin the syntactic anomaly is less likely to impede semantic integration. Some previous ERP studies (e.g., Yang et al., 2015; Yu & Zhang, 2008; Zhang et al., 2010, 2013) explored whether there is a primacy of syntax over semantics in Mandarin by testing whether there was an N400 effect, which reflects the difficulties in lexical-semantic integration (Kutas & Federmeier, 2000; Kutas & Hillyard, 1980) when processing different constructions in Mandarin such as object-subject-verb, passive and *ba* sentences (“the direct object is placed immediately after *ba* and before the verb”; Li & Thompson, 1989, p. 463) containing combined syntactic category plus semantic anomalies. The results show that they observed an N400 effect for the combined syntactic category plus semantic violations (e.g., “*Qingjiegong ba dasha de chuanghu quanbu tang le yibian*,” meaning “The dustman sugar all the windows of the edifice once”), suggesting that there is no primacy of syntax over semantics in Mandarin and an error-free syntactic representation is dispensable for semantic integration in Mandarin. These results were inconsistent with the previous ERP research in Indo-European languages (e.g., Friederici et al., 2004; Hahne & Friederici, 2002; Isel et al., 2007), in which an N400 effect was absent in the sentences of double violation (i.e., syntactic and semantic violation) such as “*Das Buch wurde trotz verpflanzt von einem Verleger, den wenige empfahlen*” meaning “The book was despite replanted by a publisher who(m) few recommended” (a German example from Friederici et al., 2004), suggesting that the semantic integration could not proceed for the syntactic violation. It seems reasonable to claim that for native Mandarin speakers the necessity of inserting a verb into the missing-verb anomalous utterances to construct a grammatical structure might be ignored by virtue of the fact that the semantic integration of the missing-verb anomalous utterances could proceed even when the syntactic anomalies exist.

Critically, however, it is premature to come to a conclusion that native speakers of English and Mandarin process missing-verb anomalous utterances differently. There is also a possibility that native Mandarin speakers tend to reconstruct a full syntactic representation due to the important influence of verbs on the syntactic representation. Such an influence is clearly reflected in previous structural priming studies in which the priming effects are influenced by the structural preferences of verbs (Melinger & Dobel, 2005) and verb position (Chang et al., 2015). Although priming really exists when the prime and target do not share the same verb, the same verb involved in the prime and target is expected to contribute to a stronger priming, i.e., the lexical boost effect (Cai et al., 2012; Huang et al., 2016; Pickering & Branigan, 1998).

Additionally, in Mandarin the flexibility of verb position necessitates the insertion of a verb into the missing-verb anomalous utterances to construct a particular complete

structure, arriving at a plausible interpretation. Specifically, the word order of Mandarin is largely determined by the meaning, causing diverse verb positions (the beginning, the middle, or the end) in sentences (Li & Thompson, 1989). For example, it might be the case that two Mandarin sentences with the same verb and nouns could possess different meanings since the same verb is located in different positions. To be specific, in these two sentences *Guke fuwuyuan zou le* (*The customer the waiter beat LE* meaning *The waiter beat the customer*) and *Guke zou fuwuyuan le* (*The customer beat the waiter LE* meaning *The customer beat the waiter*), the insertion of the verb *beat* into different locations produces opposite meanings. For this reason, after realizing the absence of a verb in a missing-verb anomalous sentence, comprehenders may reanalyze (Fodor & Inoue, 1994) the structure by inserting a verb category into different positions, which constitutes some potential constructions conveying different semantics. With the aid of non-syntactic information such as world knowledge, the most plausible structure is chosen (Crain & Steedman, 1985; Frazier & Clifton, 1998; Pickering & Traxler, 1998).

The literature discussed above shows that there could be some reasons why both the syntactic non-reconstruction and the syntactic reconstruction accounts might appear to be plausible when it comes to native Mandarin speakers. However, little prior literature provides direct and apparent empirical support for whether native Mandarin speakers process anomalous sentences with a missing verb in the same way as English native speakers do. Although Cai et al. (2013, 2015) shed light on the comprehension of missing-argument and verb-phrase ellipsis sentences in Mandarin, the sentences are grammatical elliptical expressions, which is insufficient to present direct evidence for processing ungrammatical sentences with a missing verb. Thus, we turn to the structural priming paradigm, which has been proven to be an effective experimental methodology (e.g., Cai et al., 2015; Huang et al., 2016; Ivanova et al., 2012) to investigate the comprehension of missing-verb anomalous utterances.

This study aimed to investigate the comprehension of missing-verb anomalous utterances in Mandarin. If the result is consistent with the syntactic non-reconstruction account, it shows that people from different linguistic backgrounds tend to process missing-verb anomalous utterances in different ways. In contrast, if the result supports the syntactic reconstruction account, it illustrates that the reconstruction is a universal property in the comprehension of missing-verb anomalous sentences.

## The current study

In this study, two structural priming experiments were designed on the basis of Ivanova et al. (2017), but we made some minor modifications, mainly for two reasons. First,

in the study of Ivanova et al. (2017), the procedure of the experiments was reading the prime sentences first, then making a judgment on the match pictures, and finally eliciting the description of a dative event presented in target pictures. The match pictures depicted an event involving two persons and an object (e.g., “A cowboy hits a swimmer with a hammer”). Nevertheless, there is a problem that the match pictures were likely to hint at the absence of a verb under the condition of the missing-verb primes since the match pictures described a person performing an action (hence, verb). Thus, to rule out this possibility, in our study the procedure (see Wang et al., 2020) was listening to prime sentences first, repeating the prime sentences, then judging match sentences in which the verbs were still removed following the missing-verb prime sentences and finally describing target pictures.

Another potential concern is that the priming of missing-verb anomalous utterances in Mandarin is due, in whole or in large part, to animacy rather than the syntactic structures per se. Specifically speaking, in Ivanova and colleagues’ (2017) study the ordering of animacy in the missing-verb primes was NP<sub>AN</sub> + NP<sub>AN</sub> + NP<sub>INAN</sub> (DO construction) or NP<sub>AN</sub> + NP<sub>INAN</sub> + PP<sub>AN</sub> (PO construction). Although some previous studies (e.g., Carminati et al., 2008; Xiang et al., 2022) show that animacy doesn’t account for the occurrence of priming, it is still worth considering whether the different animacy configurations (NP<sub>AN</sub> + NP<sub>INAN</sub> / NP<sub>INAN</sub> + PP<sub>AN</sub>) behind the position of the missing verb show a greater likelihood of priming the production of subsequent utterances. This might occur since the deficiency of the syntactic information caused by the missing verb raises the possibility that comprehenders are more likely to be sensitive to animacy for the reason that animacy exerts its vital influence on the processing of utterances in Mandarin (see the aforementioned studies). Since existing evidence is insufficient to determine whether animacy plays a negligible or dominant role in processing missing-verb anomalous sentences, especially in Mandarin, which lacks morphosyntactic cues, we manipulated the experimental primes in which the three entities were all animate to minimize the influence of animacy for the robustness of the priming effects. Such manipulation of animacy could be seen in previous studies (e.g., Carminati et al., 2008; Xiang et al., 2022).

In order to reconstruct the structure of the missing-verb anomalous utterances (e.g., *Wupo gongzhu yige yinger*, meaning *The witch the princess an infant*), people are expected to identify the verb position first and then fill in a verb category to combine it with other noun phrases of the sentence for a full syntactic representation. In the first experiment, the verb position of the prime sentences with a missing verb is indicated by a beep sound (e.g., *Wupo beep gongzhu yige yinger*). In the second experiment, the verb position of the prime sentences with a missing verb is not indicated (e.g., *Wupo gongzhu yige yinger*).



In the current study, participants initially hear and repeat a prime sentence with respect to differences in Prime Verb (Same Verb vs. Different Verb vs. No Verb) and Prime Construction (Double Object vs. Prepositional Object), then make a judgment on a match sentence, and finally elicit the description of a target picture. Under *the syntactic non-reconstruction account*, people comprehend a missing-verb anomalous sentence without locating the verb position and inserting a verb category to combine it with other noun phrases for a full syntactic representation, thereby adopting a literal structure for missing-verb anomalous sentences (i.e., NP + NP + NP and NP + NP + PP). Thus, no DO or PO construction is activated by the missing-verb anomalous primes. As a result, the comprehenders will be less likely to produce a DO or PO construction by using the ditransitive verbs such as *song* (give) or *huan* (return) in the target pictures. In other words, the DO and PO missing-verb anomalous primes are less effective in producing DO and PO constructions than the full-form DO and PO primes, which shows that the reduced priming following missing-verb anomalous sentences is expected, relative to the priming for the full-form sentences.

The *syntactic reconstruction account*, on the other hand, assumes a full syntactic representation for sentences without a verb, and hence predicts that the missing-verb anomalous and full-form sentences produce equivalent priming. To be specific, after the comprehenders realize the anomalous sentences lack a verb, the comprehenders are more likely to reconstruct the full syntactic representation by locating the verb position and inserting a verb category to combine it with other noun phrases of the sentence to produce a DO or PO construction (i.e., NP + V + NP + NP or NP + V + NP + PP), which makes the DO or PO construction have a higher level of activation. Thus, the DO and PO missing-verb anomalous primes are as effective as the full-form primes in producing DO and PO constructions. One point should be noted. The reconstruction of a full syntactic representation of missing-verb anomalous sentences cannot be impeded by the lack of meaning or verb-specific syntactic biases. In a previous structural priming study, Ivanova et al. (2012) did not detect any differences between the well-formed sentences and the anomalous sentences depicting dative events with novel verbs (e.g., “The waitress brunks the book to monk”) in the magnitude of priming, which shows that the reconstruction of a full syntactic representation does not rely on the lexically based syntactic information.

Aimed at strengthening the findings of Experiment 2, Experiment 1 as a control experiment is compared with Experiment 2 in the magnitude of priming. The motivation for the comparison is to increase confidence in the robustness of the conclusion by examining whether the magnitude of priming in both experiments yields no significant differences. To be specific, the verb position of

missing-verb anomalous utterances is indicated by a beep sound, which serves as an inserted verb category to show a full syntactic structure (i.e., NP + beep + NP + NP or NP + beep + NP + PP), though the meaning is unclear. As we mentioned above, the lack of some important information of the verb such as meaning and verb-specific syntactic biases could not impede the reconstruction of a full syntactic representation (Ivanova et al., 2012). Thus, the priming effects of missing-verb anomalous primes and the full-form primes (Different Verb condition) are expected to not differ significantly in Experiment 1. Compared with the literal structure (i.e., NP + NP + NP or NP + NP + PP) based on the syntactic non-reconstruction account, the reconstructed structure (i.e., NP + V + NP + NP or NP + V + NP + PP) based on the syntactic reconstruction account has stronger activation of DO and PO constructions. Thus, under *the syntactic non-reconstruction account*, the priming of Experiment 1 is larger than that of Experiment 2. Under *the syntactic reconstruction account*, the priming for both experiments yields no significant differences.

## Experiment 1

### Method

#### Participants

In total, 42 native Mandarin speakers (13 females, mean = 20.4;  $SD = 2.21$ ) with normal or corrected-to-normal vision were recruited via WeChat and they were paid to participate in Experiment 1.

#### Stimuli

In the current experiment, we constructed a total of 36 experimental items (see Appendix) and 108 filler items, which consisted of a prime sentence, a match sentence, and a target picture. The experimental prime sentences had six prime conditions (see Table 1) created by combining two factors, Prime Verb (Same Verb vs. Different Verb vs. No Verb-Beep) and Prime Construction (Double Object vs. Prepositional Object). The verbs employed in the prime sentences were *song*, *shang*, *mai*, *huan*, *dai*, and *jiao* in Chinese characters, meaning *giving*, *awarding*, *selling*, *returning*, *bringing*, and *handing* in English respectively. These verbs have been used in previous Mandarin structural priming studies (Cai et al., 2013, 2015; Chen et al., 2020; Huang et al., 2016; Xiang et al., 2022). There were a total of 101 animate entities in the prime sentences. These entities were selected from the previous Mandarin structural priming study (Xiang et al., 2022) about the independence of sentence processing in Mandarin. Xiang et al. also

**Table 1** Examples of experimental prime sentences

Prime condition	Example
(1a) Same Verb, Double Object	Wupo huan-gei gongzhu yige yinger The witch returned the princess an infant
(1b) Same Verb, Prepositional Object	Wupo huan le yige yinger gei gongzhu The witch returned an infant to the princess
(1c) Different Verb, Double Object	Wupo song-gei gongzhu yige yinger The witch gave the princess an infant
(1d) Different Verb, Prepositional Object	Wupo song le yige yinger gei gongzhu The witch gave an infant to the princess
(1e) No Verb-Beep, Double Object	Wupo <i>beep</i> gongzhu yige yinger The witch <i>beep</i> the princess an infant
(1f) No Verb-Beep, Prepositional Object	Wupo <i>beep</i> yinger gei gongzhu The witch <i>beep</i> an infant to the princess

manipulated the animacy features of postverbal nouns in the same way as the current study did ( $NP_{AN} + V + NP_{AN} + NP_{AN}$  and  $NP_{AN} + V + NP_{AN} + PP_{AN}$ ). All the prime sentences were read by a female Mandarin speaker and recorded as wav files using the software Praat.

In order to make participants concentrate more on the experiment, participants might expend much effort to distinguish the slight differences between prime sentences and match sentences. Specifically, half of the match sentences were the same as their prime sentences, which required a “yes” response, and half of the match sentences were a little different from their prime sentences, which required a “no” response. For example, the prime sentence *Jiefei beep yige renzhi gei jingcha* (*The robber beep a hostage to the policeman*) and the match sentence *Jiefei ##### yige renzhi gei laoren* (*The robber ##### a hostage to the old man*) differed only in the beneficiary. A total of 36 target pictures depicting transfer events were used. In addition, there were six verbs (*song, shang, mai, huan, dai, and jiao* mentioned above) assigned to these 36 target pictures evenly. Based on the previous Mandarin research (Cai et al., 2012, 2015; Huang et al., 2019), a preamble containing an agent and a verb appeared at the bottom of each target picture, which was aimed at producing only DO and PO constructions instead of other responses like a ba-construction or bei-construction. The arrow in the picture showed us the agent and beneficiary. For half of the target pictures the agent was positioned on the left side and for the rest it was placed on the right side. In addition, the entities in both prime sentences and target pictures were not overlapped. The target pictures were selected from the previous structural priming study (Xiang et al., 2022). An example of the experimental target pictures is shown in Fig. 1.

There were 108 fillers, which consisted of a filler prime sentence, a filler match sentence and a filler target picture. All prime fillers are monotransitive sentences. In the



**Fig. 1** An example of the stimuli. This target picture can be expressed in Mandarin as “Yisheng song-gei xuesheng yizhi bi” (The doctor gave the student a pen) or “Yisheng song LE yizhi bi gei xuesheng” (The doctor gave a pen to the student)

experiment there were some ungrammatical experimental prime sentences without a verb. Thus, in order to hide the purpose of the experiment, all the filler prime sentences were expressed in both grammatical and ungrammatical constructions in order to distract participants’ attention from realizing the aim of the experiments. Three-quarters of filler prime sentences are grammatical with a monotransitive verb (e.g., *Laoshi biaoYang xuesheng* meaning *The teacher*

*praises the student*). One-quarter of the filler prime sentences were ungrammatical. For example, in the filler prime sentence *Laoban piping* (*The boss criticizes*) the monotransitive verb *piping* meaning *criticizing* had a missing object. The filler target pictures depicted a monotransitive event. The experimental items were separated by two to four fillers. Prior to the first experimental prime sentence, there were four filler prime sentences. Six stimulus lists were created by employing a Latin-square design. The entire procedure was composed of eight practice trials, 36 experimental trials, and 108 filler trials.

## Procedure

In Experiment 1 the participants were seated in front of a PC and tested with E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) under the guise of a memory task. Before the practice and experiment trials, the participants were required to become familiar with the entities including people and objects in the target pictures. At the beginning of each trial, a red fixation cross appeared at the center of the screen. Afterwards, the prime sentence was read. After listening to the prime sentence, participants were asked to repeat the prime sentence they had heard and then press the space bar, which triggered the appearance of the match sentence. The match sentence was presented at the center of the screen and the participants needed to make a yes/no judgment about whether it was the same as the prime sentence by pressing J (yes) or F (no). After a key-press response,

a target picture appeared. After 10,000 ms or pressing the space bar, a blank screen appeared, and then the next trial repeated.

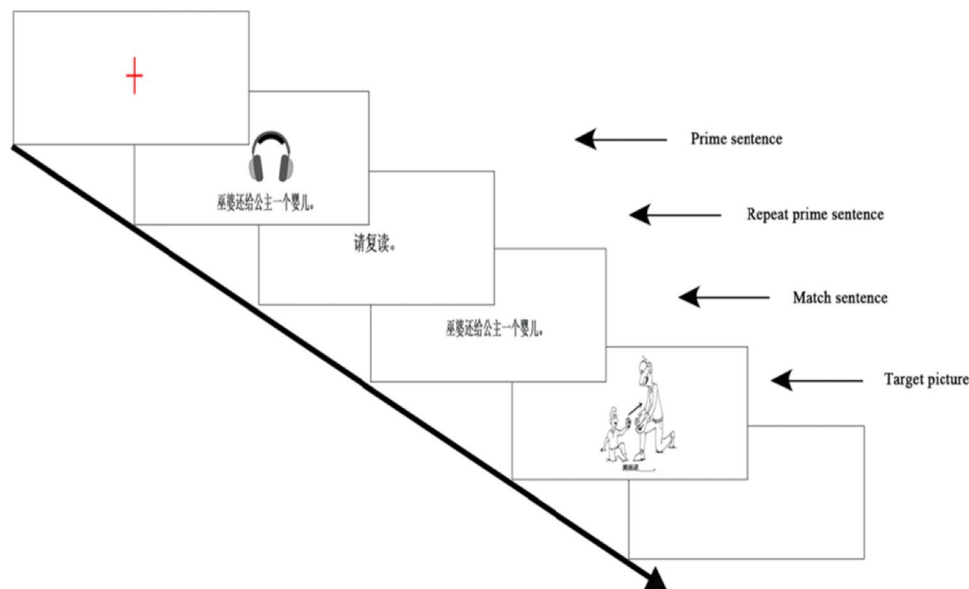
Before the experimental trials, participants were given the experimental instructions, and then they underwent a practice session of eight trials until they clearly understood how to complete each task. The instructions made no mention of the presence of anomalies in the experiment and the participants did not know the relationship between the prime sentences and target pictures. The participants were left to make of it what they could. The experiment lasted an estimated 35 min (see Fig. 2).

## Scoring

All the recordings were transcribed. Responses were scored as a PO response if the verb was followed by a noun phrase denoting the theme and then a prepositional phrase headed by *gei* denoting the beneficiary. Responses were scored as a DO response if the verb was followed by a noun phrase denoting the beneficiary and then a noun phrase denoting the theme. All other responses were coded as “Others.”

## Results

In total there were 1,512 responses, among which 678 (44.8%) were DO responses, 790 (52.2%) were PO responses, and 44 (3%) were other responses. Table 2 shows the frequency of target responses by priming type



**Fig. 2** Experimental procedure. The prime sentence means “Wupo huan-gei gongzhu yige yinger”; The characters in the picture of the repeating prime sentence mean “Please repeat what you have heard”. The match sentence means that “Wupo huan-gei gongzhu yige

yinger”. In the target picture, the Chinese characters at the bottom mean “The boy returned\_\_\_” and the identities of these two figures are the boy (on the left) and the grandfather (on the right) respectively. The “toy” is located between the two figures

**Table 2** Frequency of target responses by priming type

Priming type	DO-DV	DO-NVB	DO-SV	PO-DV	PO-NVB	PO-SV
DO	128	131	170	85	95	69
PO	113	114	80	152	152	179
Others	11	7	2	15	5	4

Note. DV Different Verb, NVB No Verb-Beep, SV Same Verb

**Table 3** Proportions of DO responses out of all DO and PO responses

Condition	DO	PO	Priming effects
Same Verb	0.68	0.28	0.40
Different Verb	0.53	0.36	0.17
No Verb-Beep	0.53	0.38	0.15

in Experiment 1. Table 3 shows the proportions of DO responses in each condition as well as the priming effects in Experiment 1.

We analyzed the data with Generalized Linear Mixed Models (GLMMs) using the lme4 package (Bates & Maechler, 2009) in R. The Other responses were excluded from analyses. In this study, the summary function of the lmerTest package (Kuznetsova et al., 2017) and the SIMR package in R (Green & MacLeod, 2016) were employed to estimate the  $p$ -values for the effects and to calculate the power of the observed priming effects respectively. Based on the principle of *Keep it maximal* (Barr et al., 2013), the maximal random effects structure was kept. Once the model failed to converge, the random effects structure was simplified from maximal to minimal. The converging model with the lowest AIC value (Matuschek et al., 2017) would be chosen as the best-fitting model. The following data analysis of Experiments 1 and 2 was similar to that of Ivanova et al. (2017).

We constructed a model in which the lexical boost effect was investigated by comparing the magnitude of priming for the Same Verb condition with that for the other two conditions (Different Verb condition + No Verb-Beep condition). Based on the orthogonal coding (Field et al., 2012; Wu, 2019), the weights of the Same Verb, Different Verb, and No Verb-Beep conditions were assigned +2, -1, and -1, respectively. Aiming to investigate whether native Mandarin speakers reconstructed the full structure of missing-verb anomalous utterances, the Different Verb and No Verb-Beep conditions were also compared in this model. The weights of the Same Verb, Different Verb, and No Verb-Beep conditions were assigned 0, +1, and -1 respectively. The results are shown in Table 4. In this model, the predictor of Prime Construction was significant, showing that DO primes produced more DO responses than PO

**Table 4** GLMER results for Experiment 1

Model	Estimate	SE	$z$	$p$
Intercept	-0.44	0.21	-2.13	<0.05
Construction	1.33	0.31	4.26	<0.01
Same vs. Diff. and No Verb-Beep	-0.27	0.06	-4.37	<0.01
Diff. vs. No Verb-Beep	<0.01	0.10	0.03	0.98

primes did. In addition, the Same Verb condition produced stronger priming than the Different Verb and No Verb-Beep conditions together did (i.e., lexical boost effect). Furthermore, the priming for Different Verb and No Verb-Beep conditions showed no significant differences.

Next, we turned our attention to the power calculation of the model mentioned above. It was observed that the power of the model exceeded 80%. In addition, the simple effects were further calculated by using the function emmeans (). The results show that all the three conditions, i.e., Same Verb ( $\beta = -2.23$ ,  $SE = 0.36$ ,  $z = -6.16$ ,  $p < 0.01$ ), Different Verb ( $\beta = -0.94$ ,  $SE = 0.36$ ,  $z = -2.64$ ,  $p < 0.01$ ) and No Verb-Beep ( $\beta = -0.81$ ,  $SE = 0.35$ ,  $z = -2.31$ ,  $p < 0.05$ ), reached statistical significance, reflecting that the priming effects were observed in all the three conditions.

## Discussion

In Experiment 1, the lexical boost effect (Pickering & Branigan, 1998) was observed since the magnitude of priming was larger when the verbs in both primes and targets were exactly the same. The appearance of the lexical boost effect was taken as strong evidence that the differences in priming effects caused by the verb could be detected. Thus, it brought confidence to the priming results of the comparison between well-formed primes (Different Verb condition) and ill-formed primes (No Verb-Beep condition). Importantly, there was no difference in the priming for both well-formed different verb primes and missing-verb anomalous primes with a beep sound indicating verb position. These results were consistent with the predictions mentioned above, showing that Experiment 1 could serve as a baseline experiment.



**Table 5** Frequency of target responses by priming type

Priming Type responses	DO-DV	DO-NV	DO-SV	PO-DV	PO-NV	PO-SV
DO	144	146	187	113	109	77
PO	121	130	91	163	158	205
Others	23	12	10	12	21	6

DV Different Verb, NV No Verb, SV Same Verb

**Table 6** Proportions of DO responses out of all DO and PO responses

Condition	DO	PO	priming effect
Same Verb	0.67	0.27	0.40
Different Verb	0.54	0.41	0.13
No Verb	0.53	0.41	0.12

**Table 7** GLMER results for Experiment 2

Model	Estimate	SE	<i>z</i>	<i>p</i>
Intercept	-0.41	0.22	-1.85	0.06
Construction	1.17	0.12	9.78	<0.01
Same vs. Diff. and No Verb	-0.26	0.06	-4.33	<0.01
Diff. vs. No Verb	-0.02	0.10	-0.15	0.88

## Experiment 2

### Method

#### Participants

Another 48 native speakers (30 females, mean = 18.3,  $SD = 2.28$ ) with normal or corrected-to-normal vision were recruited via WeChat and they were paid to participate in Experiment 2. None of the participants who took part in Experiment 1 participated in Experiment 2.

#### Stimuli, procedure, and scoring

All the stimuli were the same as the first experiment except that the No Verb-Beep prime condition (e.g., *Jiefei beep jingcha yige renzhi* or *Jiefei beep yige renzhi gei jingcha*) was changed into the No Verb prime condition (e.g., *Jiefei jingcha yige renzhi* or *Jiefei yige renzhi gei jingcha*). The procedure, scoring, and data analysis in the second experiment were the same as those in the first experiment.

### Results

In total there were 1,728 responses, among which 776 (44.9%) were DO responses, 868 (50.2%) were PO responses, and 84 (4.9%) were other responses. Table 5 shows the frequency of target responses by priming type in Experiment 2. Table 6 shows the proportions of DO responses under each condition as well as the priming effects in Experiment 2.

The same analysis as in Experiment 1 was adopted. In Experiment 2 we also first investigated the lexical boost

effect by comparing the priming effects of the Same Verb condition with those of the Different Verb and No Verb conditions together. The weight of the Same Verb condition was assigned +2, and the weights of the Different Verb condition and No Verb condition were assigned -1 and -1, respectively. In addition, the priming for the Different Verb and No Verb conditions was also compared. The weights of the Same Verb, Different Verb, and No Verb conditions were assigned 0, +1, and -1, respectively. The results of this comparison are shown in Table 7. Prime Construction was statistically significant, demonstrating that more DO responses were produced by DO primes rather than PO primes. The significant *p*-value for the comparison between the Same Verb condition and the Different Verb and No Verb conditions together shows that the repeated verb in primes and targets facilitated the magnitude of priming. In addition, the *p*-value for the comparison between the Different Verb and No Verb conditions was not significant, which indicates that the Different Verb and No Verb conditions had equivalent impact on priming.

Again we diverted our attention to the power calculation of the model mentioned above. It was observed that the power of the model exceeded 80%. Furthermore, the function `emmeans()` was used to calculate the simple effects. The results show that the magnitude of priming for the three conditions, i.e., Same Verb ( $\beta = -2.20$ ,  $SE = 0.22$ ,  $z = -10.22$ ,  $p < 0.01$ ), Different Verb ( $\beta = -0.68$ ,  $SE = 0.20$ ,  $z = -3.40$ ,  $p < 0.01$ ) and No Verb ( $\beta = -0.64$ ,  $SE = 0.20$ ,  $z = -3.20$ ,  $p < 0.01$ ), reached statistical significance, demonstrating that there were more DO responses after exposure to DO primes than after exposure to PO primes.

## Discussion

Just as in Experiment 1, the lexical boost effect was also observed, showing that in Experiment 2 differences of priming effects caused by the verb could be observed. More importantly, the structural priming effects in almost the same magnitude were observed following both well-formed different verb primes and anomalous primes with no verb. These results were consistent with the predictions of the syntactic reconstruction account mentioned above, which stood as strong evidence that people were likely to reconstruct a full syntactic representation of missing-verb anomalous utterances.

## Combined analysis of Experiment 1 and Experiment 2

In the remainder of the data analysis, the overall magnitude of priming for Experiments 1 and 2 was compared to investigate whether the overall priming effects were affected by the indication of the verb position. As in the study by Ivanova et al. (2017), the fixed effects structure contained the main effects of Prime Construction and Experiment and the interaction between Prime Construction and Experiment. The random slopes for subjects included the predictor Prime Construction but excluded the predictor Experiment since the participants of Experiments 1 and 2 were different. The results showed that Experiment ( $\beta = 0.04$ ,  $SE = 0.11$ ,  $z = 0.36$ ,  $p = 0.72$ ) and the interaction between Prime Construction and Experiment ( $\beta = -0.10$ ,  $SE = 0.16$ ,  $z = -0.60$ ,  $p = 0.55$ ) were not significant, indicating that the overall priming effects of Experiments 1 and 2 were not significantly different.

We also compared the priming effects of the Beep Verb condition in Experiment 1 and the No Verb condition in Experiment 2. The results show that the  $p$ -value for the comparison between the Beep Verb condition in Experiment 1 and the No Verb condition in Experiment 2 was not significant ( $\beta = 0.04$ ,  $SE = 0.19$ ,  $z = 0.20$ ,  $p = 0.85$ ), which demonstrates that they produced equivalent priming.

These results can be taken as strong evidence that the participants reconstructed the full syntactic structure of missing-verb anomalous utterances no matter whether the verb position was indicated or not. In other words, the reconstruction of missing-verb anomalous utterances was not affected by the indication of verb position.

## General discussion

In this study, two experiments in structural priming paradigm aimed to investigate whether native Mandarin speakers reconstructed the full structure of an anomalous sentence without a verb. In both experiments (the verb position was

indicated in Experiment 1 and not in Experiment 2), the magnitude of priming following an anomalous sentence without a verb was equivalent to that following a well-formed sentence, suggesting that native Mandarin speakers reconstructed a full constituent structure in the processing of an ungrammatical sentence with a missing verb. Thus this result is compatible with the syntactic reconstruction account, which is in accordance with the findings of Ivanova et al. (2017). There was also a lexical boost effect in both experiments, which was consistent with much previous evidence (e.g., Cai et al., 2012; Huang et al., 2016; Pickering & Branigan, 1998).

Some possible interpretations of our experimental results have been dismissed. Is it possible that DO missing-verb anomalous utterances were interpreted as the reconstructed verb-elliptical sentences? This possibility is supposed to be undermined. To be specific, the full structure of DO missing-verb utterances is NP + V + NP + NP, while NP + and + NP + V + NP is the complete structure of verb elliptical sentences. Take *Wupo gongzhu yige yinger* (The witch the princess an infant) as an example. It could be interpreted as an ungrammatical sentence devoid of a verb (*Wupo verb yige yinger*) possibly meaning that the witch gave or sold an infant to the princess. However, the full structure of verb-elliptical constructions is *Wupo* and *gongzhu* verb *yige yinger*, possibly meaning that the witch and the princess used an infant. Specifically, the reconstructed structure of missing-verb anomalous utterances (NP + V + NP + NP) is equal to a DO construction, thereby producing more DO responses than PO responses. Instead, no priming or smaller priming is likely to be found under the condition of verb-elliptical constructions since the reconstructed structure of verb-elliptical sentences (NP + and + NP + V + NP) is not equivalent to a DO construction. The experimental results of our two experiments showed that there were no detectable differences in the magnitude of priming for missing-verb anomalous utterances and full-form DO utterances (Different Verb condition). Crucially, missing-verb anomalous primes had an equivalent impact in both experiments, providing robust evidence that the structure of missing-verb DO constructions (NP + V + NP + NP) is reconstructed. It is also important to note that people are more likely to infer the possible plausible interpretation with fewer string edits (insertions and deletions) when processing semantically implausible sentences (Gibson et al., 2013). Thus, native Mandarin speakers are presumably apt to compute the syntactic representation with one deletion (e.g., *Wupo* verb *gongzhu yige yinger*) instead of two deletions (e.g., *Wupo* and *gongzhu* verb *yige yinger*). As a result, there seems to be little justification for this possibility.

Additionally, “*gei*” in the PO missing-verb anomalous utterances (e.g., *Wupo yige yinger gei gongzhu* meaning *The witch an infant to the princess*) is referred to as a coverb that

functions as a preposition (Li & Thompson, 1989). However, in Mandarin Chinese “*gei*” can also be seen as a verb meaning “giving” (Ma, 2014). Is it possible that “*gei*” in the PO missing-verb anomalous utterances was mistaken for a verb without inserting a verb category in the structure? This possibility appears to have been undermined. Once “*gei*” is interpreted as a verb without being relocated next to the subject, the utterances that become ungrammatical are not PO constructions any longer. In that case, it is much more likely that ill-formed sentences (neither DO construction nor PO construction) could not prime more grammatical PO responses than DO responses, especially when the verb position (NP + NP + V + NP) is different from that of the PO missing-verb anomalous utterances (NP + V + NP + *gei* + NP) since the verb position has an impact on priming (Chang et al., 2015). As mentioned above, comprehenders are convinced that the sentences they hear are well formed (Gibson et al., 2013). For this reason, comprehenders would not accept the unreconstructed ill-formed structure with “*gei*” as a verb. In addition, there is another possibility that “*gei*” is interpreted as a verb but the structure is reconstructed as a DO construction (NP + *gei* + NP + NP) with a legitimate word order. Despite the grammaticality, the reconstructed DO sentences are expected to prime more DO responses than PO responses. Contrary to these two possibilities, our experimental results showed that PO missing-verb anomalous utterances produced more PO responses than DO equivalents. More importantly, the missing-verb anomalous utterances and full-form primes had an equivalent impact on the magnitude of priming, thereby supporting the idea that PO missing-verb anomalous utterances were reconstructed with “*gei*” interpreted as a preposition. However, the priming effects of the two experiments were not produced by the preposition “*gei*” in the missing-verb anomalous utterances since the structural priming is not influenced by the repetition of content words (Pickering & Branigan, 1998), closed-class lexical items (Bock, 1989), metric structure, and semantic information (Bock & Loebell, 1990).

In all the experimental primes, the indefinite marker *yi* with the literal meaning *one* combined with a generic classifier *ge* (*yige*) was added to the front of the theme, showing the number. Is it possible that the indefinite marker *yi* has an impact on priming? This possibility can also be ruled out. Compared with animacy and word order, the indefinite marker *yi* is a weak cue in Chinese sentence interpretation (Li et al., 1993). Of more importance, closed-class lexical items exert no impact on priming (Bock, 1989).

Is it possible that the full-form experimental primes (Same Verb condition & Different Verb condition) provided participants with important clues as to the reconstruction of the missing-verb anomalous utterances? This possibility appears to be undermined. The comprehenders are native Mandarin speakers who possess the grammatical knowledge,

which means that they could easily judge the ungrammaticality and retrieve the verb position even when no full-form experimental primes exist. For this reason, the cues from the full-form experimental primes are not decisive for the reconstruction. More importantly, what motivates the comprehenders to reconstruct a full syntactic representation is not the linguistic environment but possibly the flexibility of verb position in Mandarin. As already noted, in Mandarin the flexibility of verb position necessitates the insertion of a verb category into different possible positions, which constitutes some potential constructions conveying different semantics. With the aid of non-syntactic information such as world knowledge, the most plausible structure is chosen (Crain & Steedman, 1985; Frazier & Clifton, 1998; Pickering & Traxler, 1998).

Our study has some important implications. Firstly, the syntactic information also plays an important part in the comprehension of missing-verb anomalous utterances in Mandarin. Without the impact of animacy, the missing-verb anomalous primes had equivalent impact in Experiments 1 and 2, showing that native Mandarin speakers reconstructed a full structure (NP + V + NP + NP/NP + V + NP + PP). Despite much reliance on semantic information such as animacy (Cai & Dong, 2007; Li et al., 1993), the comprehension of missing-verb anomalous utterances in Mandarin also proceeds smoothly, with the aid of word order coming next in importance to animacy (Li et al., 1993). As mentioned above, Mandarin offers a much greater degree of flexibility of verb position, producing various syntactic constructions including SVO, SOV, VOS, and OSV (Li & Thompson, 1989; Li et al., 1993). Thus, the flexible verb position in Mandarin potentially contributes to the reconstruction of missing-verb anomalous utterances.

Secondly, it is possible that comprehenders predict upcoming syntactic information (Staub & Clifton, 2006; Wicha et al., 2004) to construct a grammatical syntactic representation with a plausible meaning by combining the processed components with the upcoming word. The comprehenders might adopt some processing strategies such as reanalyzing the syntactic structure (Ferreira & Clifton, 1986; Fodor & Inoue, 1994; Frazier & Rayner, 1982) or adding a syntactic component for a nonliteral but plausible interpretation (Cai et al., 2022) when the predictively computed syntactic structure is incompatible with the actual input or produces an implausible meaning.

## Conclusion

The current study investigates the syntactic representation of missing-verb anomalous utterances in Mandarin. Our findings from Experiments 1 and 2 revealed that when confronting missing-verb anomalous sentences, native Mandarin

speakers were more likely to reconstruct a complete constituent structure, lending support to the syntactic reconstruction account. In the future, other constructions like topic sentence can be used as an alternative prime for DO/PO constructions. Furthermore, more studies are required to investigate the universality of reconstructing a full form of anomalous utterances without a verb in other languages unrelated to both English and Mandarin. Thus, more empirical findings should be added to a growing body of literature on missing-verb anomalous utterances.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.3758/s13421-023-01408-4>.

**Acknowledgements** We would like to express our sincere thanks to Iva Ivanova and other two anonymous reviewers for their insightful comments on the previous versions of this article. We are immensely grateful to Iva Ivanova for her inspiration, encouragement, and providing us with the precious opportunity for helpful discussion. In addition, we would like to convey our heartfelt gratitude to Chen Xiaocong and Max Dunn for the helpful discussion around the data analysis.

**Data availability** The experimental materials, experimental data, and R code associated with this study are publicly accessible at the Open Science Framework (<https://osf.io/cne6a/>).

## Declarations

**Conflict interests** The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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