The head constituent plays a key role in the lexical boost in syntactic priming

Running head: Lexical boost with head and non-head constituents

The head constituent plays a key role in the lexical boost in syntactic priming

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ABSTRACT

Accounts of language production make different predictions about the conditions under which structural priming should be enhanced by lexical repetition (the lexical boost). Repetition of the head verb strongly enhances structural priming of a sentence, but studies of English have found contradictory results regarding the effects of noun repetition. In two experiments, Mandarin participants read a prime sentence aloud and then produced a target picture description of a dative event. In Experiment 1, the verb was printed on the target picture, and we found that repetition of the verb enhanced priming (vs. no repetition) but repetition of the agent, theme, or recipient argument did not. In Experiment 2, both the agent noun and the verb were printed on the picture, and we found that verb repetition enhanced priming but agent repetition did not. These results indicate that the lexical boost is restricted to the head verb in Mandarin and therefore support lemma-based residual activation accounts of language production in which activation of a head leads to activation of its associated grammatical construction.

Keywords: Syntactic priming, Lexical boost, Head constituent, Mandarin

Introduction

When speakers produce complex utterances such as sentences, they draw on their knowledge of both the words and the syntax of the language they are using. But theories of language production have long differed in how these two aspects of language are related, in particular whether syntax is independent of the lexicon (e.g., Dell, 1986; Levelt, 1989), and understanding their relationship remains critical (see Slevc, 2023). In recent years, the development of such theories has made extensive use of speakers' strong tendency to repeat syntax (Bock, 1986), and a key question is how such syntactic priming is affected by concurrent lexical repetition. In this paper, we report two experiments using Mandarin Chinese datives that manipulated different sources of lexical repetition to discriminate between theories of syntactic priming in particular and language production more generally.

Bock (1986) first demonstrated that speakers are more likely to produce a passive sentence after encountering another passive than after encountering an active. They are also more likely to produce a so-called double object (DO) dative such as *The doctor handed the man a prescription* after encountering another DO dative such as *The teacher gave the girl a book* than after a so-called prepositional object (PO) dative such as *The teacher gave a book to the girl*. More recently, researchers found that syntactic priming occurs across different types of structures (e.g., actives vs. passives, types of noun phrases) and languages (e.g., English, German, Mandarin, Basque) (as reviewed in Pickering & Ferreira, 2008; Branigan & Pickering, 2017). Syntactic priming also occurs between languages (Hartsuiker, Pickering, & Veltkamp, 2004), particularly when they involve the same phrasal categories in the same order (see van Gompel & Arai, 2018). Finally, it occurs not only in language production, but also in language comprehension (Arai, Van Gompel & Scheepers, 2007; Ledoux, Traxler, & Swaab, 2007; Segaert, Menenti, Weber, Petersson, & Hagoort, 2012) and between comprehension and production (Branigan, Pickering, & Cleland, 2000).

Priming is enhanced when a particular word is repeated across the prime and the target – an effect known as the lexical boost (Mahowald, James, Futrell, & Gibson

2016). Pickering and Branigan (1998) asked participants to complete a target fragment including an agent and a dative verb. They found that priming was greater when the verb (the syntactic head of a dative sentence) was repeated across the prime and the target than when it was not. Similarly, Cleland and Pickering (2003) investigated the priming of complex noun phrases in dialogue, with participants selecting between adjective-noun structures (e.g., *the red sheep*) and noun-relative clause structures (e.g., *the sheep that's red*). Priming was enhanced when the noun (the syntactic head of the noun phrase) was repeated across the prime and the target (e.g., *sheep-sheep*) than when it was not (e.g., *knife-sheep*). Priming was also enhanced when nouns in the prime and the target were semantically related (e.g., *sheep-goat*) although this semantic-relatedness boost was smaller than the lexical boost.

Pickering and Branigan (1998) used the lexical boost to motivate their *lemma-based residual activation account* of how speakers construct sentences. Following Levelt, Roelofs, and Meyer (1999), they assumed that speakers have complex lexical entries for words, which are centered on so-called lemmas that encode syntactic properties and that are linked to representations of meaning and sound. According to this account, when speakers produce a sentence, they activate a node corresponding to the lemma for the verb that serves as the head of the sentence, together with nodes corresponding to its relevant syntactic properties. To produce *The teacher gave the girl a book*, they select the lemma *give*, the past tense node, and importantly a combinatorial node corresponding to the DO construction (see Figure 1).[i] They also separately activate nodes corresponding to the three argument noun phrases, but the syntactic mechanisms of production are driven by the head (i.e., the verb), rather than the noun phrases.

<Insert Figure 1 about here>

According to this account, abstract priming is a consequence of residual

activation of the combinatorial node. In our example, residual activation of the DO node means that speakers are likely to produce *The doctor handed the man a prescription* (in contrast to *The doctor handed a prescription to the man*). The lexical boost is a consequence of residual activation of the combinatorial node, the lemma node, and the link between them. Thus speakers are particularly likely to produce *The doctor gave the man a prescription* (in contrast to *The doctor gave a prescription to the man*), as the verb is repeated. This prediction is supported by many studies and in fact, the lexical boost appears to be even stronger than the abstract priming effect (see Mahowald et al., 2016; Pickering & Ferreira, 2008).

Importantly, Pickering and Branigan's (1998) lemma-based residual activation account (correctly) predicts a lexical boost for the head of the primed constituent, such as the verb in dative sentences. It also (correctly) predicts a lexical boost for nouns when priming is concerned with the form of a noun phrase (i.e., where the noun is the head; Cleland & Pickering, 2003). In keeping with the finding that levels of activation are affected by depth of processing (e.g., related to task demands; Branigan, Pickering, McLean & Cleland, 2007), the magnitude of this boost may vary. But crucially, this account makes no prediction of a lexical boost associated with non-heads, such as the noun phrase arguments of the verb. If such a boost does occur, it would require an explanation independent of this account.

In contrast to the lemma-based residual activation account, some researchers propose that the lexical boost is independent of abstract priming (Bock & Griffin, 2000), and specifically that it can be induced by explicit memory mechanisms (Chang, Janciauskas, & Fitz, 2012). We therefore refer to it as the *explicit memory account* of the lexical boost. It is largely motivated by the different time courses of the lexical boost and abstract priming: The lexical boost is (largely) short-lived, decaying rapidly when prime and target are separated, whereas abstract priming tends to persist (Bock & Griffin, 2000; Branigan & McLean, 2016; Kaschak, Kutta, & Schatschneider, 2011; Hartsuiker, Bernolet, Schoonbaert, Speybroeck & Vanderelst 2008). This account argues that abstract syntactic priming is due to implicit learning (Chang, Dell & Bock, 2006), and the lexical boost is due to explicit

memory (Chang, Janciauskas & Fitz, 2012).

According to the explicit memory account, processing of the prime sentence leaves an explicit memory trace of its surface structure. When a word is repeated in the target, it acts as a cue for retrieval of the memory trace of the prime sentence's syntactic structure, causing a lexical boost. It assumes that explicit memory of the prime sentence structure rapidly dissipates and can thus explain why the lexical boost is short-lived. It may also explain the very considerable variability in the magnitude of the lexical boost (e.g., 15% in Coyle & Kaschak, 2008 versus 73% in Hartsuiker et al., 2008), assuming that explicit memory is affected by numerous factors whose influence varies across situations (see Chang et al., 2012). However, there is no obvious reason why head and non-head repetition should differ in inducing a lexical boost since the head and non-head should act as equally valid cues in memory.

In sum, both the lemma-based residual activation account and the explicit memory account can explain the lexical boost, but they make different predictions about when it should occur. According to the lemma-based residual activation account, head repetition brings about a lexical boost, but argument repetition should not do so (because only the verb lemma is connected to the combinatorial node). According to the explicit memory account, both verb and argument repetitions should bring about a lexical boost (as both types of elements can serve as explicit cues).

Can non-head repetition induce a lexical boost?

Thus, a key difference between the lemma-based residual activation account and explicit memory account of priming is whether the lexical boost is limited to heads or not. Reitter, Keller and Moore (2011) found that the non-head repetition seems to produce a lexical boost in a corpus-based study. However, in a brief report, McLean, Pickering, and Branigan (2004) found that priming of the PO form of dative sentences (but not the DO form) was greater when the theme was repeated across the prime and the target than when there was no repetition. They also found that priming of the DO form (but not the PO form) was greater when the recipient was repeated than when

there was no repetition. Thus, non-head repetition seemed to yield a rather unstable lexical boost effect.

Three more recent studies have yielded contradictory findings. Scheepers, Raffray and Myachykov (2017) reported three experiments in which participants read a prime aloud and then constructed a sentence using four words, one of which was labeled as the word to produce first. For example, if they saw *manuscript*, *sent*, *critic*, and *editor* (where the last word had to be produced first), they could produce either *The editor sent the critic a manuscript* or *The editor sent a manuscript to the critic*. In Experiment 1, they found a priming effect that was enhanced when the agent, verb, or recipient was repeated, and a non-significant trend when the theme was repeated, and therefore argued that the lexical boost was due to explicit memory, in accord with Chang et al. (2012). Experiments 2 and 3 repeated different numbers of words between prime and target and found that priming increased as the number of repeated words increased.

In contrast, Carminati, van Gompel, and Wakeford (2019) reported four experiments using sentence completion with or without an associated picture, and found a lexical boost from verb repetition, but not from agent, theme, or recipient repetition. A fifth experiment used Scheepers et al.'s (2017) method and found no boost from the theme or recipient repetition. Their findings were therefore compatible with the lemma-based residual activation account.

These two sets of findings stand in clear opposition to each other. In Carminati et al. (2019), the null effects of an argument lexical boost might be due to their relatively small samples (28-54 participants per experiment). In Scheepers et al. (2017), the paradigm is quite removed from normal language production and effects might have a strategic origin. In addition, their measure of the lexical boost was based on comparing trials on which the prime and the target had the same structure (i.e., trials on which priming occurred) and ignoring trials on which they had different structures (i.e., trials on which priming did not occur); these are not complementary because participants sometimes produced responses that were neither DOs nor POs. For example, the agent and verb repetition boost to priming is almost identical in their

Experiment 1 (see their Table 2: .428 - .369 = .059 for the agent boost; .425 - .369 = .056 for the verb boost). But priming is considerably greater in the verb than agent repetition condition when the different structure responses are taken into account (see their Table 1: Compare the PO and DO primes for both PO and DO target responses). In addition, they varied the target rather than prime across conditions, which could introduce within-item variability that might accentuate or inhibit priming effects. Finally, they had a relatively small sample of 60 participants. Note also that Experiments 2 and 3 involved conditions with a great deal more repetition than Experiment 1 (and Carminati et al., 2019), which might induce strategic processing even when only one word was repeated.

Most recently, Van Gompel, Wakeford, and Kantola (2022) reported a lexical boost for both the verb and subject (i.e., agent) of datives when participants could see the prime while completing the target. But when participants completed the prime without being able to look back at the prime, the lexical boost occurred for the verb but not for the subject. They argued that priming of the subject was due to explicit memory, but priming of the verb was due to a mechanism such as that assumed in the lemma-based residual activation account. Finally, Kantola, van Gompel, and Wakeford (2023) used prime and target sentences such as *The hotel owner decided to the loan the tourist a tent* (i.e., containing a main verb and a subordinate dative verb). They found a boost to dative priming when the dative verb was repeated but four experiments found no boost when the main verb was repeated. Note also that although Mahowald et al.'s (2016) meta-analysis of syntactic priming found that the overall syntactic priming effect is strong, it also suggested that studies investigating whether syntactic priming is affected by the other variables (e.g., lexical repetition) tend to have been underpowered.. Therefore, it is important to conduct large-scale experiments to investigate whether non-head repetition induces a lexical boost.

Priming and the lexical boost in Mandarin

As far as we can tell, the syntactic priming effect appears universal, occurring in Indo-European languages (Pickering & Ferreira, 2008), but also in Sino-Tibetan languages, such as Mandarin (Cai, Pickering, Yan & Branigan, 2011; Huang,

Pickering, Yang, Wang & Branigan, 2016; Chen, Branigan, Wang, Huang & Pickering, 2020). Unlike English, Mandarin has few reliable cues to syntactic structure. It does not have a rigid word order and contains many words whose syntactic class is ambiguous. At the same time, it does not morphologically mark syntactic category or syntactic features such as person, number, case, or tense. Researchers have argued that semantic and contextual cues play a greater role than grammatical cues in determining who does what to whom during comprehension (e.g., Li, 1996; Li, Bates, & MacWhinney, 1993). However, syntactic priming effects do occur in Mandarin, and appear to be independent of the repetition of semantic information. For example, Huang et al. found similar priming when the recipient in the target had the same animacy as in the prime (e.g., *Mingxing song-LE changpian gei nage zhuli*; "the superstar gave the record to that assistant") as when it did not (e.g. *Mingxing song-LE changpian gei nage gongsi*; "the superstar gave the record to that company"); see also Chen et al. (2020). Moreover, dative priming occurs from English to Mandarin (Huang, Pickering, Chen, Wang & Branigan, 2019), suggesting that Mandarin and English have similar syntactic representations (that can be integrated in bilinguals).

In addition, there is a clear lexical boost due to head repetition in Chinese, as indicated in studies using a sentence/picture verification paradigm for Mandarin and Cantonese datives (Cai et al., 2011) and a recognition memory paradigm (Huang et al., 2016). This suggests that the relationship between syntactic representation and the verb is similar across languages. But there is no evidence about whether repetition of noun-phrase arguments in Chinese induces a lexical boost.

We therefore report two large-scale experiments in Mandarin that investigated whether the lexical boost was limited to verb repetition in a very different language to English, and therefore present evidence about whether the lemma-based residual activation account or the explicit memory account of formulation is cross-linguistically valid. More specifically, in Experiment 1, we used DO and PO primes to investigate the priming of datives in Mandarin, manipulating whether prime and target shared the verb, agent, recipient, or theme, or did not share any words. However, there is a potential concern with Experiment 1, namely that the verb was

printed on the target picture (to induce verb repetition), but the arguments were not (as printing theme or recipient might affect choice of target structure). Therefore, in Experiment 2, we printed the agent noun phrase and the verb on the target picture, and compared the effects of agent and target repetition on the lexical boost.

Experiment 1

Data availability

All materials, data and analysis code for the two experiments are available at https://osf.io/g2vqh/.

Participants

We recruited 200 native Mandarin-speaking participants (54 male, aged 18–28 years, mean = 20.64, SD=2.0). This study was approved by the Ethics Committee of the School of Psychology, South China Normal University. Participants were required to read and sign the consent form before the experiment, and were paid 25 RMB each after the experiment.

Items

We constructed 60 experimental items, each consisting of a set of 5 DO and 5 PO prime sentences (see Table 1) and a target picture depicting a ditransitive event containing an animate agent, an animate recipient, and an inanimate theme (see Figure 2). Most experimental materials in the pictures were taken from Branigan, Pickering, McLean & Cleland (2007). In the (DO and PO) Agent Repetition (AR) conditions, the agent of the prime sentence corresponded to the agent in the target picture (but the verb, recipient, and theme did not). In the Verb Repetition (VR) conditions, only the verb in the sentence corresponded to the verb in the picture. In the Recipient Repetition (RR) conditions, only the recipient of the sentence corresponded to the recipient of the picture. In the Theme Repetition (TR) conditions, only the theme of the sentence corresponded to the theme of the picture. Finally, in the No Repetition

(NR) condition, the agent, verb, recipient, and theme did not correspond across the sentence and the picture. We printed the Chinese character for the verb below each target picture (see Panel A in Figure 2) to help participants produce the picture description. In the target picture, the theme appeared in the center of each target picture while the positions of the agent and the recipient were counterbalanced across items.

Table 1. Example prime sentences

Prime Condition	Example (DO)	Example (PO)
Agent Repetition (AR)	修女递给画家一个球。 *Xiunv di-gei huajia yige qiu.* *Nun pass-to artist one-CL ball.* (*'The nun passed the artist a ball.'*)	修女递了一个球给画家。 *Xiunv di-LE yige qiu gei huajia.* *Nun pass-LE one-CL ball to artist.* (*'The nun passed a ball to the artist.'*)
Verb Repetition (VR)	牛仔送给画家一个球。 *Niuzai song-gei huajia yige qiu.* *Cowboy give-to artist one-CL ball.* (*'The cowboy gave the artist a ball.'*)	牛仔送了一个球给画家。 *Niuzai song-LE yige qiu gei huajia.* *Cowboy give-LE one-CL ball to artist.* (*'The cowboy gave a ball to the artist.'*)
Recipient Repetition (RR)	牛仔递给士兵一个球。 *Niuzai di-gei shibing yige qiu.* *Cowboy pass-to soldier one-CL ball.* (*'The cowboy passed the soldier a ball.'*)	牛仔递了一个球给士兵。 *Niuzai di-LE yige qiu gei shibing.* *cowboy pass-LE one-CL ball to soldier.* (*'The cowboy passed a ball to the soldier.'*)
Theme Repetition (TR)	牛仔递给画家一本书。 *Niuzai di-gei huajia yiben shu.* *Cowboy pass-to artist one-CL book.* (*'The cowboy passed the artist a book.'*)	牛仔递了一本书给画家。 *Niuzai di-LE yiben shu gei huajia.* *cowboy pass-LE one-CL book to artist.* (*'The cowboy passed a book to the artist.'*)
No Repetition	牛仔递给画家一个球。	牛仔递了一个球给画家。

(NR)	*Niuzai di-gei huajia yige qiu.* *Cowboy pass-to artist one-CL ball.* (*'The cowboy passed the artist a ball.'*)	*Niuzai di-LE yige qiu gei huajia.* *cowboy pass-LE one-CL ball to artist.* (*'The cowboy passed a ball to the artist.'*)

Note. CL=noun classifier; LE=perfect aspect marker.

<Insert Figure 2 about here>

We also constructed 120 filler items, consisting of pairs of prime sentences and target pictures, of different types: (1) 30 DO prime sentences with 30 corresponding target pictures depicting ditransitive events; (2) 45 transitive prime sentences (e.g., *Fuqin biaoyang-LE zhege nanhai*, 'The father praised the boy') with 23 target pictures depicting transitive events and 22 target pictures depicting intransitive events; (3) 45 intransitive prime sentences (e.g., *Wupo Xiao-LE*, 'The witch smiles') with 23 target pictures depicting intransitive events and 22 target pictures depicting transitive events. The verb was printed below each target picture. Note that the additional DO prime sentences (i.e., 1) were included to increase the proportion of DO target responses for experimental pictures (to offset the slight preference for PO over DO picture descriptions that are often observed in Mandarin; e.g., Cai, Pickering & Branigan, 2012).

The study had a 2 (Prime Type: DO vs. PO) x 5 (Lexical Repetition: agent vs. verb vs. recipient vs. theme vs. no repetition) within-subjects design. We created 10 lists of items, each containing one version of each item, and equal numbers of versions from each condition in a Latin-square design. Each list included 60 experimental trials (i.e., 6 per condition) and 120 filler trials, with 1-3 filler trials separating experimental trials. Participants were randomly assigned to a list.

Procedure

To familiarize participants with the names of the objects that would appear in the target, they were shown the pictures for the objects with their names printed below.

After the participants reported they were familiar with the pictures and the corresponding names, the experiment began.

For each trial, after a 500ms fixation, a written prime sentence appeared in the center of the screen. The participant was instructed to read the sentence aloud and then press the space bar to trigger the target picture. The participant described the picture by completing the sentence fragment printed below each picture, and then pressed the space bar to trigger the next trial. The experiment lasted approximately 40 minutes.

Scoring

We scored participants' responses as (1) a DO response if the sentence preamble was grammatical, and the verb was followed first by a noun phrase denoting the recipient and then by a noun phrase denoting the theme; (2) a PO response if the verb was first grammatically followed by a noun phrase denoting the theme and then a prepositional phrase (beginning with the preposition *gei*) denoting the recipient; (3) an Other response otherwise. Other responses were excluded from data analysis (and therefore DO and PO responses were complementary, in contrast to Scheepers et al., 2017).

Results

Table 2 shows the frequency of different types of responses by condition. Generally, participants were more likely to produce a PO than a DO picture description, suggesting a PO preference, in accord with previous priming studies in English and Mandarin (e.g., Scheepers et al., 2017; Carminati et al., 2019; Cai et al., 2012; Huang et al., 2016).

In data analysis, we used GLMM with crossed random effects for participants and items, using the glmer program of the lme4 package (Bates & Mächler, 2010) in R. We first coded the response as a primed or unprimed response following a particular prime structure; in this way, a syntactic priming effect would manifest as a significant intercept (i.e., whether there were more primed than unprimed responses).

Then we built a model treating Prime Type and Lexical Repetition as fixed effects. Following Scheepers et al. (2017), Prime Type was entered in the mean-centered deviation form. For Lexical Repetition, we treated the contrast between the four conditions with lexical repetition (AR, VR, TR, and RR) and the no-repetition condition to create four variables. We followed Barr, Levy, Scheepers, and Tily (2013) in adopting the model that had a maximal random effect structure and included not only by-participant and by-item random intercepts, but also by-participant and by-item random slopes for every main effect and interaction in the fixed effects of the models and the respective correlations. Because of convergence failures, we dropped random correlations in the random effect structure of the model (model equation: Priming ~ AR + VR + RR + TR + PrimeType + AR:PrimeType + VR:PrimeType + RR:PrimeType +TR:PrimeType + (1 + AR + VR + RR + TR + PrimeType + AR:PrimeType + VR:PrimeType + RR:PrimeType +TR:PrimeType || Subject) + (1 + AR + VR + RR + TR + PrimeType + AR:PrimeType + VR:PrimeType + RR:PrimeType +TR:PrimeType || Item)).

The results showed that there was a significant intercept, indicating a syntactic priming effect: in their target descriptions, participants were more likely to repeat the syntactic structure used in the prime sentence than to use the alternative structure. There was a main effect of Prime type (χ^2=0.43, Z=58.68, p<.001), indicating that priming was greater after DO primes than after PO primes. There was a main effect of Lexical Repetition (χ^2=80.68, p<.001), and the corresponding estimates (see Table 3 and Figure 3) indicated that only verb repetition, rather than any of the other three types of repetition (i.e., non-head repetition), showed a greater priming than no repetition. In other words, verb repetition produced a lexical boost, but none of the other (non-head) repetition conditions did. Finally, there was no interaction between Prime Type and Lexical Repetition (χ^2=2.15, p=0.71), suggesting that there were similar lexical boosts after PO and DO primes.

Table 2. Frequency of target responses by condition in Experiment 1.

Prime	Repetition	Target Response		
		PO	DO	Others
PO	Agent	761	234	205
	Verb	926	146	128
	Theme	785	222	193
	Recipient	772	235	193
	None	788	230	182
DO	Agent	598	390	212
	Verb	490	567	143
	Theme	599	401	200
	Recipient	613	380	207
	None	630	388	182

Table 3. Results of the fixed effects in Experiment 1

Fixed effect	*Estimated*	*SE*	*Z*	*p*
Intercept	0.97	0.07	13.85	<.001
AR	0.003	0.01	0.04	0.97
VR	1.32	0.14	9.75	<.001
TR	0.14	0.10	1.44	0.15
RR	-0.06	0.10	-0.57	0.57
Prime Type	-3.45	0.43	-8.0	<.001
VR x Prime Type	0.20	0.24	0.82	0.41
AR x Prime Type	0.23	0.20	1.19	0.24
TR x Prime Type	0.17	0.19	0.89	0.37
RR x Prime Type	0.002	0.20	0.01	0.99

<Insert Figure 3 about here>

Discussion

This experiment found that syntactic priming in Mandarin was enhanced by

repetition of the verb but not by repetition of the agent, theme, or recipient. In other words, the experiment suggests that the lexical boost is restricted to the head constituent, in accord with the lemma-based residual activation account but not the explicit memory account.

However, there is an alternative explanation of these findings. In each trial, the verb was printed on the target picture (see Figure 2A), whereas the noun-phrase arguments were not. It is possible that the visual repetition of the verb triggered explicit memory processes – that is, the printed verb may have served as a cue for participants to retrieve the verb and the corresponding syntactic structure of the prime sentence. As this cue did not exist in the other conditions, it could explain the occurrence of the lexical boost in only the verb repetition condition. This explanation is perhaps unlikely because other research has shown a lexical boost without a printed verb (Branigan & McLean, 2016, though note that their study involved a picture matching game that may have promoted the use of explicit memory processes), but it remains possible.

Removing the verb from the target picture would be likely to lead to many responses in which the verb was not repeated across prime and target (as it is difficult to depict the relevant actions unambiguously). Printing the theme or recipient on the picture might facilitate production of that argument, and therefore prime a particular structure (PO if theme was printed; DO if recipient was printed). But it is possible to print the agent without such a concern.

We therefore conducted Experiment 2 in which the target picture could be accompanied by a printed agent noun and verb (see Panel B in Figure 2). We manipulated whether prime and target shared the agent, verb, or no words, to create agent repetition, verb repetition, and no repetition conditions. In agent repetition, the prime and target shared a printed agent noun. In verb repetition, the prime and target shared a printed verb. To our knowledge, this is the first priming study to compare picture description controlling for written cues on the screen. If our observation of a lexical boost was due to explicit memory, then agent repetition should trigger an equivalent lexical boost to verb repetition.

Experiment 2

Participants

We recruited 144 native Mandarin-speaking participants (48 male, aged 19-29 years, mean = 22.74, SD=2.8). This study was approved by the Ethics Committee of the School of Psychology, South China Normal University. Participant were required to read and sign the consent form before the experiment, and were paid 25 RMB each after the experiment.

Items

We modified the materials of Experiment 1 to construct 60 new sets of experimental items, each consisting of 3 DO and 3 PO prime sentences and a target picture, on which we printed the agent noun and the verb at the bottom (see Figure 2B). In the (DO and PO) agent repetition (AR) conditions, the agent of the sentence corresponded to the agent in the target picture (but the verb, recipient, and theme did not). In the verb repetition condition, the verb of the sentence corresponded to the verb in the target picture (but the agent, recipient, and theme did not). Finally, in the no repetition (NR) condition, the agent, verb, recipient, and theme did not correspond across the sentence and the picture.

We also used the 120 filler items from Experiment 1. The study had a 2 (Prime Type: DO vs. PO) x 3 (Lexical Repetition: agent vs. verb vs. no repetition) within-subject design. We created 6 lists of items, each containing one version of each item, and equal numbers of versions from each condition in a Latin Square design. Each list included 60 experimental trials (i.e., 10 per condition) and 120 filler trials, with 1-3 filler trials separating experimental trials. Participants were randomly assigned to a list. In this experiment, there were 10 trials in each condition, whereas there were only 6 in Experiment 1. We therefore recruited 144 participants for Experiment 2 (cf. 200 participants for Experiment 1) so that the two experiments had similar numbers of observations (1440 observations per condition in Experiment 2 vs.

1200 observations per condition in Experiment 1).

Procedure and Scoring

The procedure and scoring method were identical to that of Experiment 1.

Results

Table 4 shows the frequency of different types of responses by condition. Similar to Experiment 1, participants showed a preference for the production of PO descriptions.

The data analysis process was similar to that of Experiment 1. We first coded the response as a primed or unprimed response following a particular prime structure. Then we built a model treating Prime Type and Lexical Repetition as fixed effects. The prime type was entered in the mean-centered deviation form. For lexical repetition, we treated the contrast between the two lexical repetition conditions (AR and VR) and the no repetition condition to create two variables. We adopted the maximal random effects structure in the model (model equation: Priming ~ AR + VR + PrimeType + AR:PrimeType + VR:PrimeType + (1 + AR + VR + PrimeType + AR:PrimeType + VR:PrimeType | Subject) + (1 + AR + VR + PrimeType + AR:PrimeType + VR:PrimeType | Item)).

Table 4. Frequency of target responses and proportion of primed responses by condition in Experiment 2

Prime	Repetition	Target Response		
		PO	DO	Others
PO	Agent	1041	254	145
	Verb	1128	185	127
	None	1025	270	145
DO	Agent	935	379	126
	Verb	864	452	124
	None	963	354	123

Table 5. Results of the fixed effects in Experiment 2

Fixed effect	*Estimated*	*SE*	*Z*	*p*
Intercept	0.51	0.08	6.30	<.001
AR	0.21	0.15	1.40	0.16
VR	0.74	0.17	4.37	<.001
Prime Type	-4.70	0.49	-9.61	<.001
VR x Prime Type	0.18	0.33	0.55	0.59
AR x Prime Type	0.44	0.31	1.42	0.16

<Insert Figure 4 about here>

The results showed that there was a significant intercept, indicating a syntactic priming effect. In their target descriptions, participants were more likely to repeat the syntactic structure used in the prime sentence than to use the alternative structure. There was a main effect of Prime type (χ^2=77.97, p<.001), suggesting the priming effect was larger after DO primes than after PO primes. There was a main effect of lexical repetition (χ^2=16.96, p<.001), and the corresponding estimates (see Table 5 and Figure 4) indicated that the verb repetition condition but not the agent repetition condition showed a greater priming effect than the no repetition condition. In other words, verb repetition produced a lexical boost, but the agent repetition condition did not. Finally, there was a marginally significant interaction between Prime Type and lexical repetition (χ^2=6.09, p=0.05).

Combined analysis of Experiment 1 and Experiment 2

To investigate whether there existed any difference between the two experiments in either agent repetition or verb repetition, we built a model treating Experiment (Experiments 1 and 2) and Lexical repetition (Agent repetition and Verb repetition) as fixed effects. For lexical repetition, we focused on the contrast between the two lexical repetition conditions (agent repetition and verb repetition) and the no

repetition condition to create two variables. We adopted the random intercept only structure in the model (model equation: Priming ~ AR + VR + Experiment + AR: Experiment + VR: Experiment + (1 | Subject) + (1 | Item)), since the items and participants were different between Experiments 1 and 2.

The results (see Table 6) showed that the main effect of agent repetition and the interaction between agent repetition and Experiment were not significant, suggesting that agent repetition did not produce a lexical boost in either experiment. Additionally, the results showed that the main effect of verb repetition and the interaction between verb repetition and Experiment were both significant, indicating that there was a lexical boost in the verb repetition condition and that verb repetition in Experiment 1 produced a larger lexical boost than in Experiment 2.

Table 6. Results of the fixed effects in combined analysis of Experiment 1 and Experiment 2.

Fixed effect	*Estimated*	*SE*	*Z*	*p*
Intercept	0.33	0.03	10.65	<.001
AR	0.04	0.04	1.04	0.30
VR	0.41	0.04	10.96	<.001
Experiment	-0.27	0.06	-4.42	<.001
AR x Experiment	0.05	0.08	0.71	0.48
VR x Experiment	-0.25	0.08	-3.28	0.001

General discussion

In two experiments, we investigated whether syntactic priming for sentences in Mandarin is enhanced just by repetition of the verb, or whether it is also enhanced by repetition of the agent, theme, or recipient arguments. In other words, is the lexical boost limited to repetition of the head verb, or does it occur for noun-phrase arguments as well? Experiment 1 found a lexical boost for just the verb, when the verb was printed on the target pictures. In Experiment 2, when both the agent noun phrase and the verb were printed on the pictures, we again found that the lexical boost

occurred for the verb but not for the agent. We thus conclude that the lexical boost in Mandarin is limited to the head (here, the verb).

These findings provide support for the lemma-based residual activation account of the lexical boost (Pickering & Branigan, 1998). However, they do not support Reitter et al.'s (2011) ACT-R model, which is a residual activation model that does not distinguish between heads and non-heads; and they also do not support the explicit memory account (Chang et al., 2012). In the lemma-based residual activation account, the verb-specific lexical boost is explained by a link between the head of a construction and the syntactic structures with which it is compatible (see Figure 1). Specifically, the dative verb node is linked to combinatorial nodes corresponding to the PO and DO constructions. Priming is a result of residual activation of a combinatorial node, and the lexical boost is a result of such activation together with activation of the link between the verb node and the combinatorial node (note that residual activation of an "irrelevant" verb node that is not linked to the combinatorial node such as the main verb in Kantola et al.'s [2023] study would therefore not result in a lexical boost). But there is no link between nodes corresponding to the (non-head) arguments and the combinatorial node, so argument repetition does not induce a lexical boost. This is the pattern of results that we observed in Experiments 1 and 2.

In contrast, the explicit memory account proposes that the lexical boost is a consequence of explicit memory mechanisms in which any content word can serve as an appropriate cue. According to this account, the magnitude of priming (including the lexical boost) depends on a multitude of factors that influence explicit memory (e.g., task demands, language experience), but there is no principled distinction between repetition of a head and repetition of a non-head. Whichever content word in the prime reappears in the target should induce a lexical boost. In fact, head repetition and non-head repetition should presumably trigger similar lexical boosts to each other – a prediction that was not compatible with our pattern of results.

Our findings are therefore compatible with the findings of Carminati et al. (2019), van Gompel et al. (2022), and Kantola et al. (2023). Note that van Gompel et al. did find a non-head boost when participants could see the prime when producing the

target – an effect which does appear to be due to explicit memory. But when participants could not see the prime, they found only a head boost. Therefore explicit memory does appear to affect priming under some circumstances, but it cannot explain the different patterns of head and non-head priming that we found in our experiments.

Importantly, the verb arguments occur both before the verb (agent) and after it (theme and recipient), so the lack of a boost cannot easily be explained by prime-target distance. In fact, repetition of the agent provides the strongest test case for effects of non-head arguments: If the lexical boost were dependent on explicit memory, we would expect agent repetition to yield a particularly strong boost, as it has a first-mention advantage that should enhance memory encoding and retrieval (e.g., Gernsbacher & Hargreaves, 1988; Murdock, 1962), and there is evidence for a primacy effect in within-sentence priming: Melinger and Cleland (2011) found a stronger priming of the noun phrase structure when the noun phrase occurred sentence-initially versus sentence-finally. The fact that repetition of the agent nevertheless revealed no lexical boost in Experiment 2 therefore provides strong evidence that the lexical boost is not dependent on explicit memory.

Importantly, we found a lexical boost similar to that in Carminati et al. (2019), despite using Mandarin rather than English. Thus, it appears that the relationship between the lexicon and the syntactic structure is similar in English and Mandarin. We tentatively argue that the lexicalist architecture of language production is universal – though of course further studies using languages unrelated to either English or Mandarin (as well as other constructions) are necessary to investigate this claim.

Our key finding, which discriminates between the lemma-based residual activation and explicit memory accounts, was that verb repetition induced a lexical boost in both experiments, but noun repetition did not. However, and consistent with findings from previous studies (e.g., Coyle & Kaschak, 2008; Hartsuiker et al., 2008), we also found the magnitude of the lexical boost varied between Experiments 1 and 2, with a significantly stronger boost in Experiment 1 than Experiment 2. Both of our

experiments used the same language, the same participant population, similar materials, and the same task, with the only difference being the presence of the noun on the screen. Since the lemma-based residual activation theory should not be sensitive to the presence of non-heads on the screen, it predicts a similar magnitude of priming in both studies. One way to explain this effect is that that seeing the noun on the screen reduced attention to the verb in Experiment 2 and there was comparatively more explicit processing of the verb in Experiment 1, which then modulated the lexical boost. If correct, the effects of lexical repetition on structural priming may involve some explicit memory, but of course it cannot explain our findings (together with those of Van Gompel and colleagues) as a whole.

In summary, our results suggest that the lexical boost to priming is localized to the head verb rather than its arguments. We argue that this effect supports the lemma-based residual activation account of syntactic priming during production, in which activation of the verb is associated with activation of an associated syntactic structure for which it serves as the head. More generally, it supports a lexicalist account of language production – one that appears to hold across very different types of language.

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Figure 1.

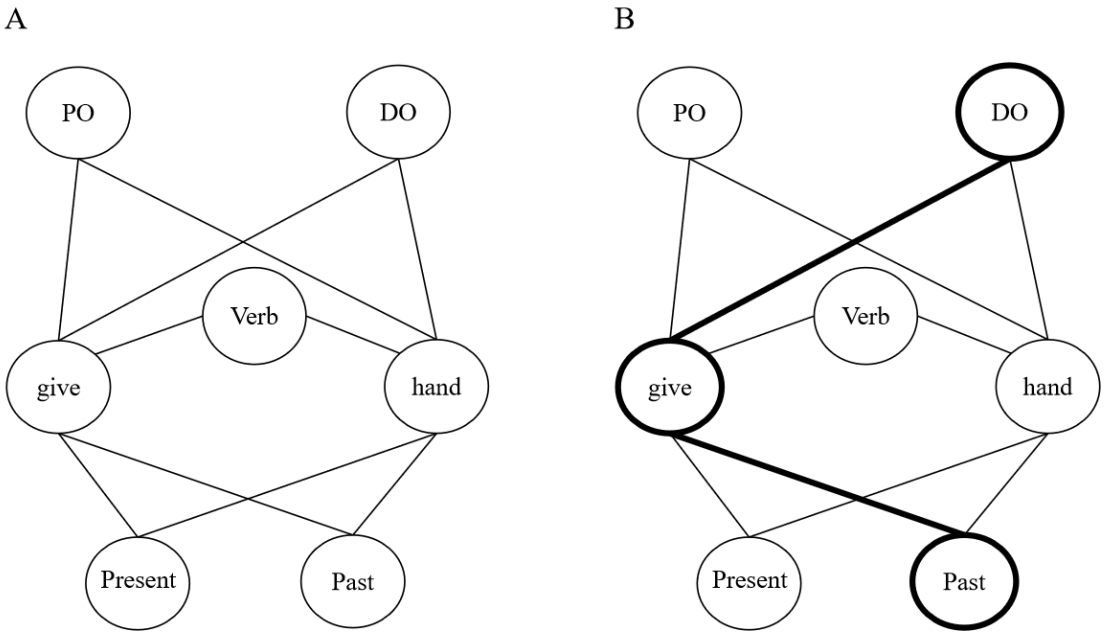


Figure 2.

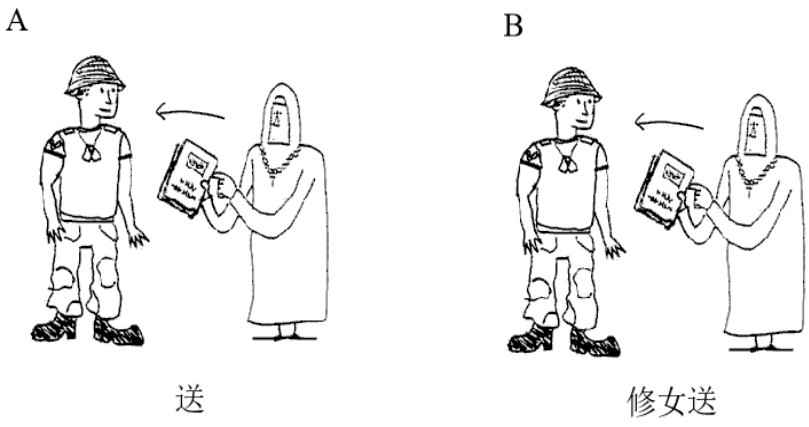


Figure 3.

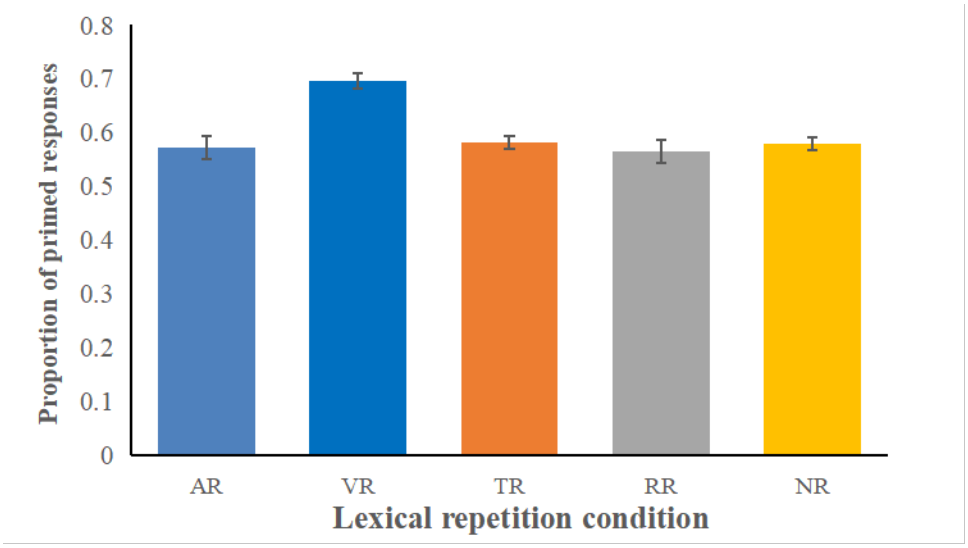
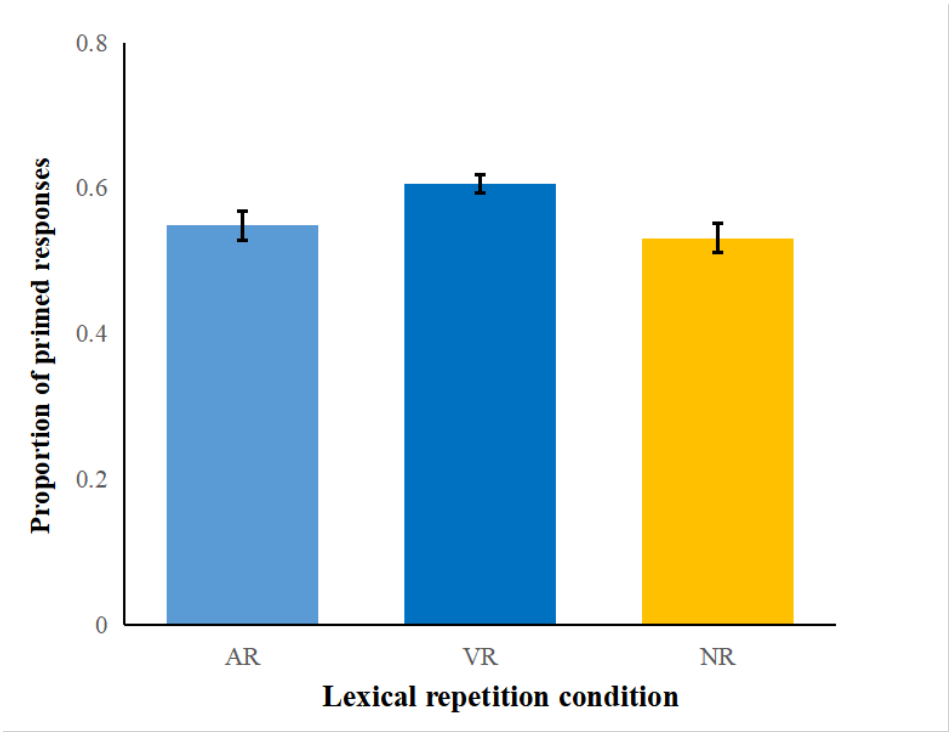


Figure 4.



List of figure captions

Figure 1.

The lemma-based residual activation account of syntactic priming as proposed by Pickering and Branigan (1998). Panel A: Before priming. Panel B: As *The teacher gave the girl a book* is produced (adapted from Pickering & Ferreira, 2008).

Figure 2.

Example target pictures in Experiment 1 (Panel A) and Experiment 2 (Panel B).

Note. The characters below the target pictures in Panels A and B mean 'give' and 'Nun give' respectively.

Figure 3.

Proportion of primed responses by repetition condition (collapsed over Prime Type condition) in Experiment 1. Error bars reflect standard errors calculated for a by-participants analysis. AR = agent repetition; VR= verb repetition; TR = theme repetition; RR = recipient repetition; NR = no repetition

Figure 4.

Proportion of primed responses by repetition condition (collapsed over Prime Type condition) in Experiment 2. Error bars reflect standard errors calculated for a by-participants analysis. AR = agent repetition; VR= verb repetition; NR = no repetition

[i] Following Levelt et al. (1999), we assume that closed class elements such as *to* in PO structures (and similarly *gei* in Mandarin PO structures) are linked to both the verb lemma and the relevant combinatorial node, and are activated alongside these nodes via "indirect election" (Kempen & Huijbers, 1983).